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# Vol. IV

EXHIBITS

## TRANSCRIPT OF RECORD

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Supreme Court of the United States

OCTOBER TERM, 1942

**No. 369**

MARCONI WIRELESS TELEGRAPH COMPANY OF  
AMERICA, PETITIONER,

vs.  
THE UNITED STATES

**No. 373**

THE UNITED STATES, PETITIONER,

vs.  
MARCONI WIRELESS TELEGRAPH COMPANY OF  
AMERICA

ON WRITS OF CERTIORARI TO THE COURT OF CLAIMS

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PETITIONS FOR CERTIORARI FILED / SEPTEMBER 2, 1942.  
/ SEPTEMBER 3, 1942.

CERTIORARI GRANTED DECEMBER 14, 1942.

SUPREME COURT OF THE UNITED STATES

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ON WRITS OF CERTIORARI TO THE COURT OF CLAIMS

VOL. IV

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JUDD & DETWEILER (INC.), PRINTERS, WASHINGTON, D. C., FEBRUARY 4, 1943.

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[fol. 2167] PLAINTIFF'S EXHIBIT No. 7

[Printed From a Certified Copy]

Royal Courts of Justice,  
Tuesday, 21st February, 1911.

IN THE HIGH COURT OF JUSTICE, CHANCERY DIVISION

Before Mr. Justice Parker

MARCONI and Others

v.

THE BRITISH RADIO TELEGRAPH AND TELEPHONE COMPANY,  
LIMITED

[From the Shorthand Notes of Cherer, Bennett & Davis,  
8, New Court, Carey Street, W. C., and of Corfield &  
Hersee, 22, Chancery Lane, W. C.]

*Counsel for the Plaintiffs:* Mr. J. M. Astbury, K. C., Mr.  
A. J. Walter, K. C., and Mr. J. Hunter Gray (instructed by  
Messrs. Coward & Hawksley, Sons & Chance).

*Counsel for the Defendants:* Mr. T. Terrell, K. C., and  
Mr. Colefax (instructed by Messrs. G. F. Hudson, Mat-  
thews & Company).

#### JUDGMENT

Mr. Justice PARKER:

This is an action for the infringement of *inter alia* the Letters Patent No. 7777 of 1900 for an invention of improvements in apparatus for wireless telegraphy. The infringement is denied, and it is contended that the Letters Patent [fol. 2168] are invalid, on various grounds to which I shall presently refer. First, however, it will be convenient to say a few words on the subject of wireless telegraphy generally, and the problems which its practical application has involved; for only in this way can a proper conclusion be reached either as to the nature of the invention or as to the soundness of the objections raised to the validity of the patent in question. Wireless telegraphy in the sense in which I am using the expression, operates by means of disturbances in the ether produced by the sudden discharge

of a Leyden jar or other condenser, and in this respect must be distinguished from inductive telegraphy which, though it also operates without the aid of wire conductors, depends for its effect upon the current which is induced in a circuit generally called the secondary circuit, when it is cut by the lines of force in the magnetic field created round itself by an electric current in another circuit usually called the primary circuit. I understand it to be mathematically demonstrable that the sensitiveness of the secondary circuit to the influence of the lines of force in the magnetic field of the primary circuit diminishes in proportion to the cube of the distance, whereas the energy of the disturbances in the ether produced by the sudden discharge of a condenser falls off only as the square of the distance. From this it seems to follow that as a means of conveying signals or messages to a distance the utilisation of these disturbances must be far more efficient than the utilisation of the lines of force in a magnetic field. A condenser can be charged in any convenient manner, and either by a continuous or by an alternating current, though the latter is preferable. Its sudden discharge is usually secured by arranging a circuit commencing in one plate and ending in the other plate of the condenser, and containing a spark gap of such a length that when in process of charging the pressure in the condenser has reached a certain point, the air between the balls of the gap is broken down, and a spark passes across the gap. Until the spark passes the circuit is incomplete, and no discharge takes place, but the spark renders the air between the balls of the gap a conductor, and by suddenly completing the circuit, causes the condenser to discharge instantaneously through the gap. What exactly happens during the exceedingly short interval of time during which the spark exists was thoroughly investigated more than half a century ago. In or about the year 1839 Henry arrived at the conclusion that during this interval the electricity [fol. 2169] with which the condenser was charged surged or oscillated with incredible rapidity through the spark gap between the positive and negative plates of the condenser. He had been studying the inductance of electric circuits, that is the effect on an electric current of the magnetic field which it creates in its own neighbourhood, and having found that inductance in electrical phenomena was in many respects equivalent to inertia in physics, he conceived of the charge in the condenser as rushing from the positive

plate through the spark gap to the negative plate overcharging such plate and then rushing back again, the process being repeated until by loss of energy due to resistance or otherwise an equilibrium was finally established.

After Henry the matter was taken up by Kelvin and Helmholtz, who not only proved by experiment and calculation that Henry's theory was correct, but established beyond all doubt the necessary conditions as to resistance, capacity and inductance of the circuit in which it was proposed to create such an oscillatory discharge and the law of the frequency of such oscillations. For the present purpose it will be sufficient to remember (1) that the resistance of such a circuit must never exceed a certain maximum which appears to be the square root of four times the inductance divided by the capacity, otherwise there will be no sudden discharge at all, but a gradual and non-oscillatory one; (2) that resistance means loss of energy and the consequent damping of the oscillations and therefore should be kept as low as possible; and (3) that the frequency though affected by the resistance of the circuit when such resistance is high depends where the resistance is low almost entirely on the capacity and inductance varying inversely as the square root of their product, so that the frequency can be increased or diminished by diminishing or increasing either the capacity or the inductance.

In or about 1868 Clark-Maxwell again devoted considerable attention to the subject, but from a different point of view. He was engaged in investigating the phenomena of light, and incidentally the nature of the ether supposed to pervade space and to be the medium by which light travels. He examined the theoretic effect which the oscillatory discharge of electricity established by Kelvin and Helmholtz would have on the ether and came to the conclusion that each complete oscillation would create an etheric disturbance or wave which would travel in all directions through [fol. 2170] space with the velocity of 300,000,000 metres a second. The wave length or distance each wave had travelled before the next succeeding wave started on its course would depend on the frequency of the oscillations, being the velocity of 300,000,000 metres divided by such frequency. If the frequency were 1,000,000 the wave length would be 300 metres, and so on. It is unnecessary to attempt to explain even if I were able how or why such waves must theoretically be created by an oscillatory electric dis-

charge or their precise nature. It will be sufficient to say that their properties are such that if and whenever they strike across a circuit capable of carrying an oscillating current of electricity they will induce or tend to induce in such circuit electrical oscillations corresponding in frequency with their wave length.

What Clark-Maxwell proved theoretically, Hertz demonstrated as a fact. He arranged his discharge circuit in such a way that the oscillations would readily part with their energy to the surrounding ether, his idea being to increase the amplitude of the waves and make them easier to detect. For this purpose he opened his circuits by separating the two plates of his condenser. Further, by reducing the capacity and inductance of his circuit as much as possible, he increased the frequency of his oscillations, his object or one of his objects being to create short waves which would be more convenient for laboratory experiments. In this way he arrived at what is known as the Hertz radiator. In order to detect the ether waves created by his radiator, he bent a piece of wire in the form of a hoop, the two ends slightly overlapping each other, and one fitted with a sharp point, which though it nearly touched the other in fact left the tiniest of intervals by way of a spark gap. Lastly, he conceived the idea of rendering his detector more sensitive by utilising as far as possible the principle of sympathetic resonance. Inasmuch as this principle plays a considerable part in the invention covered by the patent in question, I shall have to deal with it somewhat fully. Just as it is possible to start a clock by a series of gentle taps administered to its pendulum, provided that the taps follow each other at intervals of time corresponding with the time period of the pendulum's swing, so that the series of taps has a cumulative effect on the pendulum and no one of them undoes the work another has done: just as in an analogous way it is possible to make a violin or piano string sound by singing in its neighbourhood its own appropriate note, the sound [fol. 2170<sup>1</sup><sub>2</sub>] waves following each other at the appropriate intervals of time, so that each wave adds to the effect of the waves which have preceded it, and none of them undoes what another has done, so Hertz conceived that if his detector were tuned to the same time period as his radiator, the series of ether waves created by the latter would have an accumulative effect on the former, and this effect would be easier to detect. With this object, proceeding according

to the laws established by Kelvin, he adjusted the inductance and capacity of his detector, so that it had the same time period as his radiator. By means of his detector so tuned and placed in his laboratory at some little distance from his radiator he for the first time established experimentally the truth of Clark-Maxwell's theory showing how the ether waves due to the electric oscillations in the radiator striking across the detector induced in the latter an oscillating electric current which manifested itself by a minute spark in the tiny spark gap. This was in the year 1889, and in 1890 Branly, working on the same lines, first used for the detection of ether waves what is known as the coherer principle based on facts which I understand had been previously discovered at any rate as to metals by Lodge. A glass tube containing metal filings is a bad conductor by reason of the imperfect contact between the filings, but if it be subjected to the influence of an electric current, contact between the filings is established or improved, they cohere, and the tube becomes a good conductor. If such a tube, therefore, be placed in the circuit of a battery the circuit is incomplete because the tube is not a conductor and no current passes. Branly arranged such a tube so that while still in the battery circuit it could be subjected to the influence of the oscillating current induced in the detector by the ether waves. When so subjected he found that the filings cohered, the tube became a conductor completing the battery circuit so that the battery current passed and moved a galvanometer also contained in such circuit. It thus became possible to detect the existence of the ether waves by an ordinary galvanometer. Inasmuch however as the filings in the coherer when once they have been made to cohere under the influence of an electric current continue to cohere until their contact is mechanically destroyed, it is necessary in order to detect a succession of signals that some mechanical appliance should be provided whereby the contact should be destroyed and the tube rendered non-conductive as soon as the galvanometer had had [fol. 2171] time to move. In 1892 the result of Hertz's experiments was becoming generally known, and Crookes in an article in the "Fortnightly Review" first suggested that it might lead to a system of wireless telegraphy based on the creation and detection of ether waves. In 1893 Hertz died, and in the following year Lodge lectured before the Royal Institution on Hertz's work in connection with ether

waves. This lecture, which was repeated at Oxford shortly afterwards, was an event of great importance, not only because it brought the subject upon which Hertz had been experimenting prominently before the scientific world, but because in it Lodge explained with great exactness the various difficulties attending the full utilisation of the principle of sympathetic resonance for the purpose of the detection of ether waves. It is these difficulties which Marconi claims to have overcome by the invention the subject of the patent in question in this action, and I propose, therefore, to state them as clearly and shortly as I am able. To start a clock by gently tapping its pendulum not only must the taps be rightly timed with reference to the period of the pendulum, but there must be a long series of taps of approximate equal strength. Again, to set a violin or piano string sounding by singing to it its own appropriate note the note must be sustained so as to give a long series of sound waves of approximately equal amplitude. In like manner, if the principle of sympathetic resonance is to be utilized to its full extent in the detection of ether waves there must be a long series of waves of equal, or approximately equal, amplitude. Such a series of waves can only result where the oscillations from which they proceed occur in a circuit which loses its energy very slowly, for, as the energy in the circuit decreases, so does the amplitude of the ether waves which it creates. It must not, therefore, waste its energy either by internal resistance, or by giving it out too lavishly to the surrounding ether. On the other hand, if ether waves are to be detected at any great distance, they must be waves of substantial amplitude, for their effect diminishes as the square of the distance, and to create waves of any substantial amplitude, the oscillating circuit must give up its energy readily to the surrounding ether. It follows that a circuit which is a good conserver of energy, and therefore one capable of creating a series of waves of approximately equal amplitude is a bad radiator; and, on the other hand, a good radiator, which will perhaps surrender 70 to 80 per cent of its energy to the ether during each [fol. 2172] oscillation is necessarily a bad conserver of energy, and will not create a long series of waves of approximately equal amplitude, but one big wave followed by a short train of waves of rapidly diminishing amplitude. On the other hand, if the problem be looked at from the point of view of the detector there is a similar difficulty. A

good radiating circuit will be a good absorbing circuit, but it will not be a good conserving circuit. In other words, the more susceptible it is to the ether waves the less it is fitted to accumulate and store up the effect of a train of waves, because its tendency is to part forthwith with any energy it receives. This being so, it follows that the arrangements Hertz himself made were in the nature of a compromise; his radiator was a good radiator but a bad oscillator; it readily gave out its energy to the ether, but the waves it created were not a train of waves of approximately equal amplitude. Its oscillations were rapidly damped, not by internal waste due to resistance, but by external loss, and the resulting ether waves consisted of one wave of great amplitude followed by a few others of rapidly diminished amplitude. On the other hand, Hertz's detector, being an approximately closed circuit, was not a good absorber capable of use at great distances, but, on the other hand, it was a good conserver of energy, and therefore well calculated to accumulate the effect of a series of waves. In one of the experiments which Lodge showed at his lecture before the Royal Institution he used an approximately closed circuit both for his radiator and for his detector, getting his effect by great precision of tuning, but he was careful to point out that a closed circuit is both a feeble radiator and a feeble absorber, and not therefore, adapted for action at a distance. Lodge summed up the difficulty in these words: "The two conditions of conspicuous energy of radiation and persistent vibration electrically produced are at present incompatible." This is as true as when Lodge said it, if we remember that he was referring to a single circuit. On the 2nd June, 1896, Marconi applied for his patent in connection with wireless telegraphy No. 12039 of 1896. This was the first patent ever granted for a system of wireless telegraphy based on the creation and detection of ether waves. It embodied a great number of details which need not be considered. It will be enough to remember the following points: In the first place, Marconi made use of an open circuit both to create and detect his waves: in other words, to use the terms now in vogue, his transmitter [fol. 2173] was a good radiator and his receiver a good absorber, though by virtue of these very qualities the former could not create nor the latter accumulate the effect of such a series of waves of equal amplitude as would be necessary for utilising to the full the principle of sympathetic reso-

nance. Nevertheless, for what it was worth he tuned the two circuits together as Hertz had done. In the next place, Marconi replaced the horizontal Hertz radiator by a vertical wire of considerable height connected through a spark-gap to the earth. These improvements were admittedly a great advance, though the precise reason why a vertical aerial with a connection to earth is so much more effective than a horizontal or unearthed aerial appears to be a matter of considerable doubt. Lastly, he made use in his receiver of an improved Branly coherer connected with a mechanical arrangement for decohering the metal filings by a continuous and rapid series of taps. I gather that with the apparatus described in his first patent, without the aid of any subsequent improvement, Marconi, or the Plaintiff Company, which in 1897 was formed to work the patent, succeeded in sending messages over a distance of many miles, and thus fully demonstrated the possibility and utility of a system of wireless telegraphy based on the creation and detection of ether waves.

Marconi's system, as shown in his 1896 patent, had, however, several drawbacks: not only was there the drawback explained by Lodge that his transmitter being a good radiator could not create, and his receiver being a good absorber could not store up the effect of such a long train of waves as was required for utilizing the principle of resonance, but there was also the farther drawback that the electric energy he could get into his transmitter was somewhat limited. In the first place, the charge which his transmitting circuit would hold was limited by its capacity, and the capacity of a vertical wire such as he proposed to use is not great, nor is it practical to increase it very greatly by increasing the length of the wire or by the addition of capacity areas. In the next place, the voltage which could be obtained in such a circuit was limited by the tendency of an open circuit, consisting of a vertical wire, to a brush discharge. His store of energy was thus limited, and, such as it was, he could not employ it economically, because he could not get such a series of waves as was necessary for fully utilising the principle of resonance. It is necessary to [fol. 2174] bear these drawbacks in mind in considering the next patent to which I shall refer.

On the 10th of May, 1897, before the acceptance of Marconi's complete specification, Lodge applied for his patent No. 11545 of 1897 for improvements in syntonised teleg-

raphy without line wires. In this patent he returns to the problem of using the principle of sympathetic resonance in a system of wireless telegraphy, laying stress not only on its effectiveness at great distances but on the fact that it enables one or more receiving stations with properly tuned receivers to receive messages without other stations with receivers tuned to different frequency or wave length being in any way disturbed; in other words, in order to secure a selectivity which for practical purposes is of the greatest moment. He was, of course, confronted with the difficulty he himself had explained in his lecture, namely, the impossibility of a good radiator being a persistent vibrator or of a good absorber being a good accumulator, but he recognized that if he could get a long series of waves he could afford to diminish the amplitude of the first few of them. He therefore compromised matters by increasing the persistence of vibration of his radiating circuit at the expense of its radiating qualities and increasing the accumulative power of his receiving circuit at the expense of its absorbing qualities. Both circuits as in Marconi's 1896 patent were open circuits, but Lodge effected his compromise by the introduction of an inductance thus for the purpose of syntony obtaining a somewhat longer series of waves of approximately the same amplitude, while at the same time he increased his available energy by the introduction of two capacity areas, of such a shape as to minimise the tendency of his circuit to a brush discharge, thereby increasing the amperage of his oscillations and their possible potential. It will thus be seen that he appreciated the drawbacks I have mentioned as incident to Marconi's 1896 system and to some extent met them. In other respects his system resembled Marconi's. His aerial was vertical and not horizontal, and he says it may be earthed if desired, and he too uses a coherer of metal filings with a mechanical de-cohering arrangement.

Later the same year Lodge applied for another patent, No. 29505, of 1897. This relates to inductive telegraphy and its only importance for the purposes of this case, if indeed it has for such purposes any importance at all, is that the [fol. 2175] primary and secondary circuits used by him have adjustable arrangements for precise tuning and are tuned to the same frequency, so that the secondary, which, like the primary, is a closed circuit, may operate by accumula-

tion on the principle of resonance and that selectivity may be secured.

This was followed in 1898 by Silvanus Thompson's patent, No. 525, of 1898, which also relates to inductive telegraphy and follows the same lines. I do not think that either of these patents throws any light on the difficulties incident to utilising the principle of resonance in a system of telegraphy based on the creation and detection of ether waves.

The next patent to which I must refer is Marconi's patent No. 12326 of 1898. The invention disclosed includes an improved receiver in which the aerial is connected to earth through the primary of a transformer, the secondary circuit of which contains the coherer, his object being to step up the voltage so as to ensure that the coherer will more readily be affected. He goes with great detail into the construction of the transformers appropriate for his purpose. They are all of them air core transformers such as had been used by Tesla for the purpose of stepping-up the voltage of alternating currents of exceedingly high frequency. Marconi subsequently obtained two further patents, No. 6982 of 1899, and No. 25186 of 1899, relating to this form of receiver. I have now mentioned all that I consider necessary to the interpretation of Marconi's patent of 1900, which is the patent in question in this action. It is true that this patent was preceded by Braun's patent No. 1862 of 1899, which is relied on as an anticipation, and with which I shall have to deal presently. But there is no evidence that Braun's patent was put into practice or became generally known before the date of Marconi's patent of 1900, and I cannot, therefore, treat the former as relevant to the true interpretation of the latter.

I will proceed, therefore, to consider Marconi's patent of 1900. Marconi commences his specification with the statement that the object of his invention is not only to increase the efficiency of the apparatus theretofore employed, but to secure selectivity. To any electrical engineer conversant with the problems of wireless telegraphy this statement would, I think, at once suggest Lodge's patent of 1897, and the difficulties it was intended to meet, namely, the difficulty of obtaining such a train of waves as was necessary for selectivity, and the difficulty of increasing the available store of energy in the transmitter. The specification then refers to the transmitter described in Marconi's 1896 patent,

with its vertical wire connected to earth through the spark gap, and proceeds as follows: "According to the present invention, the vertical wire is connected to earth through the secondary winding of a transformer of a kind suitable for the transformation of very rapidly alternating electric currents, and the primary of this transformer is connected to the spheres or terminals of the sparking appliance. A condenser of suitable capacity is introduced in series with the primary." The effect of this arrangement is reasonably clear. He gets two circuits, the circuit of the primary containing a condenser, which could be of any desired capacity, with the usual provision for its discharge through the spark gap, and the circuit of the secondary, containing the vertical wire. This device, he says, enables much more energy to be imparted to the radiator than heretofore, the approximately closed circuit of the primary being a good conserver, and the open circuit of the secondary being a good radiator of wave energy. Here, at any rate, he obviously refers to the difficulty explained by Lodge, and proposes to meet it without any sacrifice such as Lodge's patent involved. Lodge has said with truth: You cannot have your circuit doing two incompatible things, however desirable, at the same time. Marconi says, in effect: Take two circuits and let one do one of the things and the other do the other. The electrical engineer reading the specification would thus be led not only to expect a long train of ether waves created through the medium of an open radiating circuit by persistent oscillations occurring in a closed conserving circuit, but an actual increase in the total available energy of the radiating circuit, this increase depending on the conserving qualities of the closed circuit. In other words, the latter would be a reservoir of energy for the former. The inventor then proceeds to describe how this result is brought about. The arrangement, he says, works as follows: On pressing the key and actuating the induction coil in order to produce a signal, the condenser in circuit with the transformer (he means, of course, the primary of the transformer) is charged and subsequently discharges through the spark gap. If the capacity, the inductance, and the resistance of the circuit are of suitable values, that is, if the conditions worked out by Kelvin are fulfilled, the discharge [fol. 2177] is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer and induce similar oscillations in the sec-

ondary, these oscillations being communicated to the elevated conductor (that is, to the radiating aerial), the circuit of which should be suitably attuned for the purpose. There is no doubt that this means tuned to the primary circuit. The object of this tuning is nowhere expressly stated, but I think the only reasonable inference is that the object was to get the full effect of the principle of sympathetic resonance as between the primary and the secondary circuits; in other words, that the long train of oscillations of equal amplitude which would take place in the primary because it was a good conserver of energy might, on the principle of resonance, gradually build up, and thereafter maintain, a like train of oscillations in the secondary.

In maintaining this train of oscillations in the secondary the primary would thus be playing much the same part as the mechanism which in a clock supplies at the appropriate time the energy lost by the pendulum in its swing. In this way more energy would be imparted to the radiator first because the energy of the primary circuit could be increased by choosing a condenser of suitable capacity, and secondly, because the primary circuit, being a good conserver of energy, could act as a reservoir, on which the radiating circuit could draw as required. The inventor next states that the effect of the oscillations in the elevated conductor or aerial is to inductively affect similar distant conductors or aeri-als if the self-induction and capacity of the latter are of suitable value or values. This appears to me to point to the cumulative effect of a train of ether waves created by the transmitting aerial upon the receiving aerial if the latter be tuned to the former. Then, after stating at the receiving end a receiver is employed such as is described in the Marconi patents of 1898 and 1899, to which I have already referred, that is a receiver in which the vertical wire is connected to earth through the primary of a transformer, the secondary of which contains the coherer, the inventor proceeds as follows: "The four circuits, namely, those including the primary and secondary of the transformer in the transmitter and the primary and secondary of the transformer in the receiver, should be so adjusted as to make the electric time period the same in each, that is the product of the self-induction multiplied by the capacity, the [fol. 2178] same in each. But in lieu of the time periods being the same in each they may be harmonies of each other." In other words, all four circuits are to be tuned together.

He does not expressly state the object of tuning between the circuits in the transmitter and the circuits in the receiver, but this would be sufficiently clear to anyone acquainted with the progress of wireless telegraphy, more especially as he does state how selectivity is thereby secured. Nor again does he expressly state why the two circuits of the receiver are to be tuned together, but this again is I think sufficiently indicated by what he has said of the circuits in the transmitter. The primary circuit of the receiver is a good absorber but a bad conserver of energy, and, therefore, not adapted to store up the cumulative effect of a long train of waves. He means this accumulation to take place in the secondary circuit of the receiver to make sure that the coherer shall be broken down and the signal get through. He is not now proposing to use a transformer for the purpose of raising the voltage of a current to act on the coherer, but for the purpose of getting a circuit which will accumulate the effect of a train of waves without the absorbing qualities of his aerial being affected. The rest of the specification is taken up with a detailed description with reference to drawings of the apparatus he proposes to use and minute directions as to how such apparatus is to be varied so as to be attuned to nine distinct time periods, or, as he calls them, tunes. The claims are reasonably clear. The first is for a transmitter for electric wave telegraphy, consisting of a spark producer having its terminals connected through a condenser with one circuit of a transformer, the other circuit being connected to a conductor and to earth or a capacity, the time period of electrical oscillations in the two circuits being the same or harmonics of each other. I think the words "or a capacity" are only introduced lest someone using the invention should say there was no infringement because there was no earth connection. The second claim is for a system of electric wave telegraphy in which both the transmitter and the receiver contain a transformer the time period of electrical oscillations in the four circuits of the two transformers being the same or harmonics of each other. The third claim is for a system of electrical wave telegraphy in which both the transmitter and the receiver contain a transformer one circuit of which is a persistent oscillator and the other a good radiator or absorber of electrical oscillations, all four circuits having the same time period or being harmonics of each other, substantially as described. This claim corroborates what I have said as to

the use of the two circuits in the receiver being tuned together. The fourth claim is for apparatus for wireless telegraphy substantially as described and illustrated in the drawings.

The interpretation I have put on the patent in question appears to me after careful consideration the true and indeed the only possible interpretation, but before leaving the subject I ought to deal with a matter on which considerable stress was laid at the trial. All the scientific witnesses agreed that the cumulative effect of the oscillations in one circuit upon another circuit tuned to it depends upon how the two circuits are coupled together. To get the full cumulative effect the circuits must be what is called loosely coupled, for the cumulative effect of the primary on the tuned secondary diminishes as the coupling is tightened. The specification contains no express direction as to whether the circuits are to be loosely or tightly coupled, but once more all the scientific witnesses were at one in thinking that in 1900 to an electrical engineer a direction to get a cumulative effect in one circuit by means of the oscillations in another tuned to it would be in effect a direction to couple the circuits loosely, though the defendants' witnesses doubted whether they would have read the specification as giving this direction to get a cumulative effect.

In my opinion this direction is impliedly if not expressly given in the specification. The inventor wants selectivity which it was known required a train of waves of approximately equal amplitude. No tight coupling would secure this train of waves. The inventor wants his primary to act as a reservoir of energy for his tuned secondary and loose coupling would be necessary if the energy in the reservoir were to be used economically and to the best advantage. Further, an examination of the detailed apparatus described in the specification as appropriate for each of the nine specified tunes shows that in every case, except one, the coupling between the circuits is very loose, while in the excepted case it is sufficiently loose to allow of some considerable cumulative effect, and the plaintiffs' witnesses proved that this effect was sufficient for practical purposes. The question of coupling was further proved to be important in the following respect. By reason of some reaction of the secondary on the primary circuit, there must always be a tendency to the production of oscillations of two distinct time periods, [fol. 2180] and consequently of ether waves of two distinct

lengths. This tendency diminishes as the looseness of the coupling between the circuits increases. If the coupling is very loose, it may be ignored for practical purposes, and the ether waves may be treated as a single series of waves of equal length, but if the tightness of the coupling be increased, we have two series of ether waves of two distinct wave lengths. In one of the tunes dealt with in the specification, the tightness of the coupling is 30 per cent. (absolute tightness being represented by 100) and with this degree of tightness there are admittedly two series of ether waves of two distinct wave lengths. It appears, however, that this so far from being a disadvantage, may at times be convenient, for a distant receiver will respond if tuned to either wave length. It must be remembered that there is no plea of insufficiency, and all this matter of tight or loose coupling is relevant only on the question of interpretation. The suggestion is that I ought not to interpret the patent in a manner which would give rise to doubts as to its insufficiency, and that, if I interpret it as including tight as well as loose coupling, such an interpretation would assist the defendants in establishing their pleas of invalidity based on want of utility, anticipation by Braun's 1899 patent, and want of subject matter. Having come to the conclusion that the specification in effect contains a direction to couple the circuits loosely, so that the effect of the primary on the secondary may be cumulative, I need not further pursue the matter.

As I interpret the patent, the essential features of the invention thereby disclosed are as follows: In order to get over a well-known difficulty in applying the principle of resonance as between transmitter and receiver in a system of wireless telegraphy, a difficulty involved in the impossibility of a single circuit being at once a good radiator, or absorber and a persistent oscillator, the inventor proposes to substitute for a single circuit in both transmitter and receiver a pair of circuits, one of which is so constructed as to radiate or absorb readily and the other of which is so constructed as to oscillate persistently and be a good conserver of energy. The two circuits of the transmitter are tuned together, and linked by means of a transformer in such a way that electrical oscillations in the closed and persistently oscillating circuit build up, and, inasmuch as the primary can act as a reservoir of energy for the secondary, maintain similar oscillations in the

[fol. 2181] open and readily vibrating secondary. Similarly, the two circuits of the receiver, tuned to the same time period as the circuits of the transmitter, are linked through a transformer in such a way that electrical oscillations in the readily absorbing primary build up similar oscillations in a closed and conserving secondary until such oscillations have strength to break down the coherer.

It is not disputed that if this be the invention it does get over to a very great extent if not entirely, the difficulty it was designed to meet. The open and readily radiating circuit of the transmitter produces a long train of ether waves of approximately equal amplitude without any sacrifice of its radiating qualities, and with an increased available energy, the energy given off by each oscillation being replaced by energy drawn from the closed and persistently oscillating primary circuit. The open and readily absorbing circuit of the receiver itself, unable to accumulate the effect of a long train of waves without a sacrifice of its absorbing qualities, hands over the task to a closed and conserving secondary circuit, which accumulates such effect until the coherer breaks down and the message gets through. Further, if this be the invention its utility is undoubted, for it at once doubled the distance to which effective messages could be sent by means of ether waves and effectively secured selectivity in all cases in which the receiving stations were not so near as to be disturbed by single waves or the first three or four waves of a series. Having ascertained the essential features of Marconi's invention, I propose next to consider whether it was anticipated by Braun's patent No. 1862 of 1899. Braun's patent involves many difficulties. The inventor commences his complete specification by classifying electrical vibrations into three groups: 1, those with the low frequency of ordinary alternating currents mechanically produced; 2, those with the much higher frequency of oscillations produced by the discharge of Leyden jars with or without induction coils in circuit, which I take to mean with or without the introduction into the circuit of inductances for the purpose of lowering the frequency and increasing the resulting wave length; 3, those of the enormous frequency produced by Hertz, not by means of Leyden jars and special induction coils, but by ordinary conductors, the capacity and induction of which is relatively small. He proceeds to state that for wireless telegraphy inventors have hitherto confined their attention

[fol. 2182] to the third group which he calls Hertzian waves, their one object being to increase the frequency. He then mentions a certain practical inconvenience involved in using waves of very high frequency, and says that his invention is intended to obviate this inconvenience and that he does this by making use of electrical oscillations belonging to the second group and having only a small frequency compared with the frequencies hitherto adopted. It is reasonably clear on the evidence that Braun was imperfectly acquainted with what was being done by Marconi. The latter was already using and Lodge had proposed to use electrical oscillations which would belong to the second of Braun's groups. Braun proceeds as follows: "Another, and perhaps even more important advantage in using slower vibrations is that their potential and amplitude, and thereby the energy transmitted is more easily increased. When the Hertzian waves are used there is a certain length of spark which must not be exceeded if the circuit is required to excite vibrations, otherwise the vibrations would be damped too much, the constraint of the system giving way gradually instead of suddenly, but this means that the effective potential is limited, which if slower oscillations are used either does not occur or can be very easily avoided." There was a great deal of controversy at the trial as to what this passage means, and whether it is sense or nonsense, and I do not think that any complete agreement was arrived at. It is fairly clear that Braun is proposing to increase the energy transmitted to the ether by his radiating circuit and considers that this result may be attained by increasing the potential and amplitude of the electrical oscillations in such circuits, and he further considers he can more easily increase such potential and amplitude if he uses slower oscillations. He points out what I conceive to be the fact that if Hertz waves be used the potential or voltage cannot exceed the voltage which is sufficient to break down the spark gap. He further points out that if in order to get a higher voltage you begin to increase the length of the spark gap, you are soon pulled up by Kelvin's law as to the maximum resistance allowable if there are to be electrical oscillations at all, for to increase the length of the spark gap is to increase the resistance in the circuit. This also, I conceive to be true. Unfortunately, what he says of Hertz waves is equally true whatever the

wave frequency. In no case can you increase the length of the spark gap indefinitely without being pulled up by [fol. 2183] Kelvin's law. He may mean that you can get a greater allowable resistance if you use longer waves, that is, if you increase the product of the capacity multiplied by the inductance, but if the maximum allowable resistance is the square root of four times the inductance divided by the capacity, this must depend upon whether you increase such product by increasing the inductance or increasing the capacity, that is not on increasing the wave length, but on the means adopted for securing such increase. Further, it is not clear on the evidence whether you could by increasing the wave length in any way obtain a higher potential in the oscillations resulting from the discharge of the condenser, the maximum potential is limited not only by the length of the spark gap but also by the tendency of the circuit to a brush discharge, and in other ways, and this renders the problem one of considerable complexity. Braun next proceeds to say that he has found that the oscillations produced by the discharge of Leyden jars of usual size in a circuit having moderate self-induction are very convenient for the purpose of transmitting signals and that the experiments also show that with an equal expenditure of energy in the transmitting circuit it is preferable to use the slower vibrations. Here again it is by no means clear to what he is referring, unless it be to the practical inconvenience already mentioned as incident to the use of Hertzian waves. Braun then says that the Leyden jar or whatever other apparatus is used for the production of the electric impulses is connected with the spark gap of a Ruhmkorff apparatus or a Wimshurst influence machine and provided with the well-known vertical sending wire preferably of considerable length and that in the receiving station the ordinary arrangement may also be used for the vertical receiving wire, the coherer, local battery and signalling device, such as Morse or the like. Obviously, in this passage he is referring to things which he conceives to be in common use and to form no part of his own invention. To what he is referring is, however, again a difficult question. An electrical engineer might, no doubt, at first sight consider the reference to be to Marconi's vertical aerial, which, at the date of the patent, was, in fact, of considerable length, but then an electrical engineer conversant with the art would or might on second thoughts be

led to doubt this, for he would be well aware that Marconi was already using frequencies of the class which Braun claimed to be using for the first time, and would, [fol. 2184] therefore, conclude that Braun was unacquainted with Marconi's aerial, and meant merely a vertical wire of very small inductance and very small capacity, such as, if used by itself, would involve great frequency of vibration. Further, if, notwithstanding this, he took the reference to be to Marconi's usual apparatus both in the transmitting and receiving stations he might not improbably conclude that Braun did not intend to tune, for he is apparently decreasing the frequency of the transmitting circuit without providing for any corresponding decrease in the frequency of the receiving circuit. Braun proceeds to say that in order that his invention may be clearly understood he has shown in the accompanying drawings, by way of example, some arrangements of circuits for transmitting signals by means of the electric oscillations above described, that is by means of oscillations of his second group, but he adds that his invention is not limited to the precise arrangements shown, for these can be varied very considerably and electrical oscillations of a low frequency suitable for transmitting signals according to his invention can be produced in various other ways. This obviously means that the essential feature of his invention is the use of frequencies of his second group however produced and not in any particular means of producing them. Accordingly his first claim is for the improvement in the transmission of electrical signals without connecting wires which consists in using electrical vibrations of comparatively low frequency such as are produced by the discharge of Leyden jars with or without induction coils in circuit substantially as described. He has a second claim to a combination of apparatus substantially as described.

I have now examined the letterpress of Braun's specification without any particular reference to his drawings and I think it clear that such letterpress does not contain even the remotest suggestion of the problem which Marconi's patent of 1900 was intended to solve much less any suggestion bearing on its solution. If, therefore, the latter patent has been anticipated by anything in Braun's specification it must be by something disclosed in Braun's drawings. All these drawings are diagrammatic, no working details whatever being given, and if anything approaching Marconi's

1900 invention is to be got out of them it can only be by supplying the working details in such a way as will secure the object Marconi had in view. The Drawing No. 1 shows [fol. 2185] the vertical wire or aerial connected with the inner coating of a Leyden jar, the inner and outer coatings of which are connected to the two small balls of a spark gap, the circuit also containing a small induction coil. Drawing No. 3 shows the same arrangement, a pair of Leyden jars in series being substituted for a single Leyden jar. The Drawings No. 2 and No. 4 correspond to the Drawings No. 1 and No. 3 respectively, with this exception that in them the induction coil is shown as the primary coil of a transformer, one of the terminals of the secondary being connected to the vertical wire or aerial and the other in Drawing No. 2 to the outer coating of the jar, and in Drawing No. 4 to some capacity, possibly the earth. It appears from the letterpress that the object of this transformer is to step up the voltage. This cannot, I think, be taken as showing the manner in which the inventor conceived that the potential of his circuit might be more easily increased by using oscillations of less frequency, for it is a method equally applicable to oscillations of any frequency. Its effect, however, in achieving the object in view would depend largely on the conditions of the two circuits as to tight or loose coupling as also on their relative capacities, the maximum possible voltage in the secondary increasing as its capacity decreases. As appears from the body of the specification Braun evidently conceived the well-known vertical wire to which he referred to be of very small capacity compared with the Leyden jar he proposed to introduce into his transmitter, and also that the circuit of this Leyden jar would be the circuit which determined both the energy transmitted to the ether and the length of the ether waves. He says nothing as to the time period of the secondary circuit though possibly he thinks he can increase the potential of the oscillations in it by means of a transformer, probably just because it had relatively small capacity. He must, therefore, I think, have contemplated that the time period of the primary would be forced on the secondary, whatever its natural time period, which could only be effectively done by the tightest possible coupling. This conclusion is corroborated by the Drawings No. 1 and No. 3 in which, strictly speaking, there is one circuit only. Even if, as is possible from one

point of view, these drawings be looked upon as containing two circuits, those circuits are as tightly coupled as may be, though here again the degree of tight or loose coupling would depend on working details which, as well as any suggestion of tuning the two circuits, are altogether absent. [foi. 2186] My conclusion is that though any one with a knowledge of Marconi's 1900 invention could easily adapt Drawings No. 2 and No. 4 to obtain his result by supplying appropriate working details, including tuning appliances, and otherwise, the drawings themselves do not, any more than the letterpress, contain any suggestion either of the problem — of the working details appropriate to its solution. It follows that Braun's specification does not in any way anticipate Marconi's 1900 patent unless indeed it can be shown that an electrical engineer, acting in the light of what was generally known at the date of Braun's patent, must have necessarily arrived at Marconi's result. I cannot think this to have been the case. In my opinion any competent engineer would most probably have put Braun's specification altogether aside as being founded on a mistake as to the frequencies then in use and otherwise containing so many points of difficulty. He would have said Marconi is already doing what this man claims and it is useless pursuing the matter further. Even if he had been struck with and desired to test the apparatus diagrammatically shown in the drawings, there would be no reason why he should work on Drawings No. 2 and No. 4 rather than on those numbered 1 and 3, unless his object was to get high voltage in the vertical wire. If he desired higher voltage he would I think have coupled his circuits as tightly as possible and rushed his current through. Even if he had thought of tuning he would have thought of it only in connection with securing a high voltage and not in connection with securing a cumulative action by the primary on the secondary so as to get a long train of waves. That I am right in this conclusion will be further evident when I consider, as I must now proceed to do, the objection to Marconi's patent founded on want of subject matter. In considering the plea of want of subject matter it is important to notice that in the receiver the mere introduction of two circuits instead of one was no novelty. In Fig. 14 of Lodge's 1897 Patent he shows the open circuit of his receiving aerial linked through a transformer with a closed

circuit containing the coherer, his idea being as he states to leave his receiving aerial freer to vibrate electrically without disturbance from attached wires. The secondary circuit as shown is not tuned to, nor can it be tuned to, the circuit of the aerial. This, in my opinion, is exceedingly strong evidence that Marconi's 1900 invention was not so obvious as to deprive it of subject matter. Here [fol. 2187] was Lodge, an electrical engineer of first-rate ability, actually devising means to get over the difficulty he had himself explained in his lecture, the difficulty that a good radiating or absorbing circuit is a bad oscillating circuit and a bad conserver of energy. To get over this difficulty, he is making a compromise at both ends by partially sacrificing the radiating or absorbing qualities of his aerial. He introduces two circuits at the receiving end, and yet he does not see that if only he utilised the principle of resonance, as between those two circuits the problem would be solved, at any rate at the receiving end, and really the problem at the transmitting end is the same problem from the reverse point of view. The common knowledge of the art was so far as material for the present purpose, the same when Lodge prepared his 1897 specification as when Marconi prepared his 1900 specification. How then can I treat as obvious at the latter date what so able a man as Lodge entirely failed to see at the former date, how far Lodge was from grasping the advantage of having two circuits is also apparent from his Fig. 4. In this he has, in a way, two circuits in his transmitter, but his object is not to use one as a reservoir for the other, but, on the contrary, when once he has charged his radiating circuit to separate it entirely from its source of supply. Again, in his 1898 patent Marconi introduces in his receiver a pair of circuits linked through a transformer, his object being to raise the voltage in the secondary and thus give the coherer in circuit with the secondary a better chance of breaking down. He does not, any more than Lodge, tune the two circuits together as he might have been expected to do if tuning them were really so obvious a matter. In the two patents of Lodge and Silvanus Thompson relating to induction telegraphy the transmitter and receiver are tuned and it is of course true that transmitter and receiver in such a system may be looked on as the primary and secondary of an exceedingly loosely coupled transformer, but induction telegraphy in-

volves no such difficulty in the application of the principle of resonance as is involved in telegraphy by ether waves, and the tuning in these cases bears really no analogy to the tuning of a pair of circuits in Marconi's system. Then again the defendants referred to Tesla's Patents of 1891 and 1896 as containing information from which anyone in 1900 would have known that two transformer circuits ought to be tuned together. In his first patent, Fig. 1, Tesla shows a transformer by which he proposed to raise the [fol. 2188] voltage of the oscillations produced by the sudden discharge of a condenser for the purpose of lighting lamps. His circuits, therefore, are coupled as tightly as may be, no tuning being suggested, if indeed tuning be possible at all. In Tesla's second patent he make a great point of tuning his circuits, but while on the one hand he directs the tuning of some circuits which cannot possibly be tuned together he fails on the other hand to give any direction at all for the tuning together of his discharge and working circuits, the only pair of circuits a direction to tune which might have been relevant. This is rather curious, because in a lecture delivered by him in 1893 he showed a transformer the secondary of which contained an adjustable condenser for the purpose of tuning it to the primary. In this lecture he had discussed the theory of resonance generally, but expressed doubts as to its utility if applied to any system of telegraphy without the aid of wires, and I should infer that in 1896 he doubted its utility as applied to any of the purposes within the scope of that patent.

There was some evidence that the manufacturers of Tesla transformers before they sell them adjust the primary to the secondary in such a way that if the terminals of the secondary are connected by short wires with the balls of an adjustable spark gap they get the longest possible spark. This is said to be tuning but if it is the tuning is destroyed by the terminals being connected to any other circuit when the apparatus is in use. There was some evidence too that when Tesla transformers are used in the laboratory the operator adjusts the secondary to the primary by varying the number of turns in one or both till he gets the best result. This also is said to be tuning, but Mr. Swinburne, who has great experience in such matters, says that until he came into court he never heard of any such practice.

I can hardly hold, therefore, that it was common knowledge that where a transformer was used the circuit of the primary and secondary should be tuned together. Finally it is said and truly said that Oudin used high frequency transformers in which the primary and secondary circuits were tuned. I think the whole of the evidence in this respect may be summed up as follows. High frequency transformers had been used for the purpose of stepping up voltage and for this purpose only. For stepping up voltage the transformer coils should be coupled as tightly as possible, that is so arranged that all or as many as possible of the lines of force in the magnetic field of the primary [fol. 2189] should cut the secondary coil. But however tightly the transformer coil may be coupled, the tightness of the coupling of the circuits of which they form part will depend on the relative values of the mutual and self-induction existing in the system, and the conditions may therefore be such that a really tight coupling becomes impossible. It was found that in such a case the effect of the transformer in stepping up the voltage was diminished unless the two circuits were adjusted, and this adjustment was in reality a rough tuning of one circuit to the other. The object was in every case to overcome the disadvantage of the coupling being loosened by the prevailing conditions of the circuits, and to get the maximum effect in raising the voltage in the secondary. This is the most that can be said, and I am not clear that even this was a matter of general knowledge. The application of tuning to cure the necessary evils of loose coupling is very different from deliberately coupling two circuits loosely and tuning them together in order that one may be a reservoir for and have an accumulative effect on the other and thus create such a long train of waves as was necessary for securing the full benefit of resonance between the receiver and transmitter in a system of wireless telegraphy. Marconi does not use his transformer to secure higher voltage or for any purpose for which a transformer so far as the evidence goes had ever been used before. In the literature quoted there is no trace of the idea underlying his invention nor, so far as I can see, a single suggestion from which a competent engineer could arrive at this idea. I hold, therefore, that the plea of want of subject matter entirely fails.

The only other plea of invalidity is based on a suggested prior grant contained in Braun's second patent of 1899, the

complete specification of which was not accepted or published till after the date of Marconi's 1900 patent, and which, therefore, could not be relied upon as an anticipation. This plea of prior grant was not, I think, really pressed. Braun's second patent in effect claims the arrangement shown in Figs. 2 and 4 of his earlier specification, except that the aerial is earthed in each case. He may have applied for this subsequent patent because the provisional of his earlier patent did not in any way foreshadow Figs. 2 and 4, or because he had found Figs. 2 and 4 more satisfactory with an earthed aerial. He says nothing of tuning, and his specification contains a passage which in my opinion is inconsistent with the two circuits being intended to be tuned together. I cannot see how it can be said that [fol. 2190] this patent contains a grant of the invention described in Marconi's 1900 patent.

Having come to the conclusion that Marconi's 1900 patent is a good and valid patent, I must now proceed to consider the question of infringement. The defendants propose to make use of a system of wireless telegraphy called the Balsillie system and fully described in a pamphlet entitled the Balsillie System of Radio Telegraphy which was put in at the trial. It is admitted that they have offered for sale apparatus made in substantial accordance with this pamphlet and have actually sold and installed such apparatus on board a ship called the "Nonsuch." Further, it is reasonably clear on the evidence that the apparatus described in the pamphlet and actually installed on the "Nonsuch" has the following characteristics. The transmitter contains two circuits one a closed circuit which is a good conserver of energy and a persistent oscillator, and the other an open circuit which is a good radiator. These circuits are intended to be tuned together and contain adjustable devices by which the capacity or inductance, or both, may be varied for that purpose. They are also linked together in such a way that the oscillations in the closed circuit will gradually build up and maintain like oscillations in the open circuit, so that the latter produces a long train of ether waves of approximately equal amplitude and not one big wave followed by three or four of rapidly diminished amplitude. Similarly the receiver has two circuits, one an open circuit which is a good absorber and the other a closed circuit which is a good conserver of energy. These circuits also are intended to be

tuned together and also to the time period of the circuits in the transmitter and have tuning devices for that purpose. They are also so linked that the oscillations induced in the open circuit by a train of waves may have a cumulative effect on the closed circuit gradually building up oscillations of sufficient amplitude to be readily detected. It appears, therefore, that the defendants' apparatus contains all the essential features of the invention protected by Marconi's 1900 patent. How then can it be said that there is no infringement?

The defendants' contention that there is no infringement is based on the following considerations: In the apparatus described by Marconi, the two circuits of both the transmitter and the receiver are linked through what he calls a transformer, and it is clear at any rate in the body of the specification that he is contemplating an instrument with two [fol. 2191] separate coils. The defendants say that the word "transformer" is in ordinary parlance confined to a two coil instrument, and that Marconi's claims (at any rate, when read with the body of the specification) are limited to a transformer in its ordinary sense with two separate coils. They say that they have not themselves used any such instrument and do not intend to use any such instrument in their transmitter. If they intend to use any such instrument in their receiver, which they have not yet done, Marconi, they say, cannot complain, for he has not claimed his receiver separately, but only in conjunction with his transmitter. The instrument they have used and so far at any rate as their transmitter is concerned intend to use is not a two coil instrument but a single coil instrument. It is not in ordinary parlance a transformer at all, but what is known as an auto-transformer; it does not, they say, act as the transformer acts entirely by mutual induction, but partly by mutual induction and partly by what is called inductive shunt, and they can, they say, perfectly easily eliminate the mutual induction altogether and make their instrument act entirely by inductive shunt. Further they say that their auto-transformer is a new discovery so that the doctrine of equivalents has no application.

On these grounds they contend that they have not infringed and will not infringe Marconi's patent by any use of the Balsillie system described in the pamphlet. There was at the trial a considerable amount of evidence directed to this question of infringement, and on such evidence I

have come to the following conclusions. The name transformer was originally given to instruments used for stepping up or stepping down the voltage of an electric current and had direct reference to the effect produced. Thus, the instrument by which a current of 30 amperes and 100 volts was transformed or converted into a current of 10 amperes and 300 volts, or *vice versa* was appropriately called a transformer. The instrument originally and most generally used to step up or step down voltage had two distinct and separate coils. The amount by which the voltage was stepped up or stepped down depended on the number of turns in the secondary compared with the number of turns in the primary coil. If the number of turns in each was precisely the same, and the coils were tightly coupled in the sense that all the lines of force in the magnetic field of the primary cut the secondary, then theoretically the voltage in [fol. 2192] the secondary would be the same as in the primary and there would be no transforming effect in its original sense at all. An instrument so arranged might, however, serve other useful purposes as for example where it was desired to avoid in a working circuit any metallic connection with the source of supply though it was not desired to step up or step down the voltage and an instrument so arranged became known as a "1 to 1" transformer, that is, a transformer which strictly speaking had no transforming effect but had other uses. As soon as the word "transformer" came to be used as including an instrument which had no transforming effect on the current, the word not unnaturally began to connote not any change in the voltage but a transformation of electrical energy in one circuit into magnetic energy in the field and back again into electrical energy in another circuit, in other words, that the current in the secondary was an induced current. Meanwhile, it had been discovered that for the purpose of stepping up or stepping down voltage an instrument need not have two separate coils. The same effect could be obtained if the instrument had a single coil, part of which was common to both circuits and the whole or part of which was in one circuit only; the extent to which the current was stepped up or down still depending on the number of turns in the secondary as compared with the number of turns in the primary. This instrument was originally sold simply as a transformer, but it became generally known as an auto-transformer to distinguish it from a transformer which still generally de-

noted an instrument with two separate coils. It should be noticed that in an auto-transformer if the whole coil is common to both circuits there is no step up or step down in voltage and, therefore, no transforming effect in the proper sense of the word. It is a 1 to 1 auto-transformer. Further, if the whole coil is common to both circuits the element of mutual induction is eliminated and the instrument operates entirely by inductive shunt. It was suggested during the trial that inductive shunt does not involve the conversion of electrical into magnetic energy and its re-conversion into electrical energy in the secondary circuit, so that on the footing that the word "transformer" connotes such conversion and reconversion a 1 to 1 auto-transformer is not a transformer in any sense of the word. This suggestion could not however be sustained. In considering the action of the inductive shunt in an auto-transformer, at any rate when employed in such a system as the defendants', it is [fol. 2193] necessary to concentrate one's attention successively on the conditions prevailing at different moments during the time period (itself exceedingly minute) during which an oscillation takes place. These conditions are continually varying for the oscillations in the secondary are necessarily out of step with the oscillations in the primary. I think that all the expert witnesses finally agreed that though at some moments electrical energy might be passing from the primary to the secondary circuit without any conversion into or re-conversion from magnetic energy yet at other times the electrical energy in the secondary consists to a great extent if not entirely of energy, derived originally it is true from the primary but which has undergone such conversion and re-conversion; in other words, there are times in which the electrical energy in the secondary is the result of induction pure and simple. There would appear, however, to be this difference, between a 1 to 1 transformer with two coils and a 1 to 1 auto-transformer, namely, that the whole coil being in both circuits the element of mutual inductive effect between the parts of the coil in one circuit and the parts of the coil in the other circuit may be said to be eliminated, but this is a question of words rather than of substance if as seems to be the case the 1 to 1 auto-transformer operates mainly by induction. Long before 1900 the theory of auto-transformers had been worked out and it had been proved and was known that whatever the mode in which they acted they could be arranged to produce

the same effect in the secondary as an ordinary transformer with two coils and they were extensively used for transforming purposes instead of ordinary transformers whenever there was no particular reason to avoid metallic connection between the secondary circuit and the source of supply. A 1 to 1 auto-transformer was not however used, there being no obvious purposes for which it might be useful. Its properties, however, were I think equally well known. Before Tesla's experiments with currents of high frequency and great potential the transformers and auto-transformers in general use were provided with iron cores, such cores affording an easy path for the lines of force in the magnetic field. Tesla found that for stepping up high frequency currents the iron core was a disadvantage and his transformers were air core transformers. Marconi made use of air core transformers in his patents of 1898 and 1899 and no doubt refers to them in his 1900 patent when he speaks of transformers suitable for the transformation of very rapid alternating electric currents. It does not appear that air core auto-transformers had ever been used prior to this patent except by Oudin whose papers will be found in the green book containing the papers relied on by the defendants in their objections. I cannot conceive, however, that an electrical engineer in, say, 1899 would have any doubt that what could be done by an air core two coil transformer could also be done by an air core auto-transformer. Of course in applying any electrical instrument for the first time to produce a desired effect an engineer may possibly meet with some unforeseen difficulty, but I am satisfied that if at the date of Marconi's 1900 patent a competent electrical engineer conversant with wireless telegraphy had had Marconi's invention explained to him and had been asked whether you could substitute for Marconi's two coil transformers auto-transformers whether arranged one to one or otherwise, he would unhesitatingly have answered in the affirmative, and if this be so the use of the air core auto-transformer even if arranged one to one in Marconi's system could never have afforded subject matter for a new patent or be called a new discovery.

Under the circumstances to which I have referred it is not unnatural that the plaintiff should be able to quote numerous cases in which the word "transformer" has been used to include auto-transformer or in which an auto-transformer has been called a transformer, and that on the other

hand the defendants should be able to quote numerous instances in which an instrument is called an auto-transformer to distinguish it from an ordinary transformer with two coils. When the word "transformer" is used, its meaning must depend largely on the context. My general impression is that anyone who ordered a transformer from a manufacturer of electrical instruments would expect to get and would be supplied with a two coil instrument. On the other hand, a contract for electrical works in which transformers *simpliciter* are specified for purposes not requiring the absence of metallic connection between the secondary and the source of the supply would, I think, be complied with by providing auto-transformers. There can, I think, be no doubt that anyone reading first the body of Marconi's Specification and then his claims, would conclude that the instrument he refers to in the claims as a transformer was an instrument with two coils, though the words of the claims taken alone might include auto-transformers. If therefore the use of an instrument with two coils were [fol. 2195] an essential feature of the invention the action would fail. In my opinion, however, the use of a two coil instrument is not an essential feature of Marconi's invention at all. The essential features of his invention I have already stated and will not repeat. The merit of the invention lies in the idea rather than in the particular means by which he carries it out. Given the problem consisting in the difficulty of a single circuit doing two inconsistent things at the same time, given the idea of solving this problem by a division of labour between two circuits tuned together and linked so that the cumulative effect of resonance might come into play between them, it would not I think have been very difficult for any competent engineer to work out the details. Clearly some form of inductive linkage (to use Mr. Dugald Clerk's expression) would be necessary and Marconi took, and I think most engineers would have taken, the most obvious means of securing this linkage, namely, a two coil transformer. It is, however, a matter of indifference so far as the essence of this invention is concerned whether a transformer or an auto-transformer be used. Looking at the first claim of the specification it is a claim for a transmitter involving a combination of parts, and among others two tuned circuits and a transformer, the latter supplying the necessary linkage. In the second and third claim the transformer has the same function. The

fourth claim is for apparatus substantially as described in the specification and illustrated in the drawings. Turning to the defendants' apparatus it seems to me that it contains everything of real value in every single claiming clause, the only difference being that the necessary inductive linkage is supplied through an auto-transformer and not through a two coil transformer, and this in no way affects the result. It is a well-known rule of patent law that no one who borrows the substance of a patented invention can escape the consequences of infringement by making immaterial variations. From this point of view the question is whether the infringing apparatus is substantially the same as the apparatus said to have been infringed. In the present case I cannot doubt that a jury would say that the defendants' apparatus was substantially the same as that shown in Marconi's 1900 patent. Again, where the patent is for a combination of parts or a process, and the combination or process, besides being itself new, produces new and useful results; everyone who produces the same results [fol. 2196] by using the essential parts of the combination or process is an infringer even though he has in fact altered the combination or process by omitting some unessential part or step and substituting another part or step which is in fact equivalent to the part or step he has omitted. The question here again is one of the essential features of the invention said to have been infringed. If that part of the combination or that step in the process for which an equivalent has been substituted be the essential feature or one of the essential features, there is no room for this doctrine of equivalents, and to ascertain the essential features of an invention, the specification must be read and interpreted by the light of what was generally known at the date of the patent. A good instance of the application of the doctrine will be found in the case of *Benno Jaffe und Darmstadter Lanolin Fabrik v. John Richardson & Co.* in the 11th Patent Office Reports, pages 93 and 261, where the use of a centrifugal machine in the process was both specified and claimed but the process was a new process and led to a new and useful result, and a defendant who had used the whole process, omitting the centrifugal machine and substituting a settling tank to do what the centrifugal machine had been intended to do, was held to be an infringer, for the use of a centrifugal machine was not an essential feature, but the means used to secure one particular result in a

process which was itself new and produced a new result. It was argued that the doctrine of equivalents has no application where the equivalent used was unknown at the date of the patent. I do not think this can be accepted as a correct proposition of law. It would for example be absurd to hold that a person who had invented a new mechanical device which would have the same effect as, say, a cam, could lawfully make use of all patents in which a cam formed part of or was a step in the combination or process specified or claimed. The argument was based entirely on *Heath v. Lunn*, in 5 House of Lords Cases, page 505. That case however does not appear to me really to support the argument. The patent there was for a process of manufacturing cast steel by the use in the melting pot of a specified quantity of carburet of manganese, an expensive metallic substance. The use of this particular substance was of the essence of the invention and no one who did not use it could possibly infringe. The defendant had not used it, at any rate directly; he had put into the melting pot a paste made [fol. 2197] of oxide of manganese and coal tar. There was evidence however that in the melting pot this paste produced carburet of manganese and that the carburet of manganese so produced was the operative agent in securing the beneficial result. Did the defendant then infringe the patent by this indirect use of carburet of manganese? It was held not. The fact that the paste produced the carburet in the melting pot was a new and valuable discovery. Had it been known at the date of the patent that a paste of coal tar and oxide of manganese when put in the melting pot produced carburet of manganese and had it been also known at the date of the patent in what proportions you ought to use the two former substances to produce in the melting pot the required proportion of the latter substances there would have been an infringement not by virtue of the rule of equivalents to which I have been referring in connection with a non-essential feature of the invention, but because there would have been an actual use of an essential feature. No use of any substance other than carburet of manganese, however well known it was at the date of the patent that such substance would have the same chemical effect as carburet of manganese could have infringed a patent in which the use of carburet of manganese was an essential feature. When the use of a particular chemical substance is of the essence of the invention, the inventor must of course be

taken to have claimed the use of that substance to the exclusion of all other chemical substances (see *Nobel Explosive Company v. Henderson*, 12 R. P. C., 164), and there is no room at all in such a case for the doctrine of equivalents in the ordinary sense of the expression. But a claim to the use of a particular substance may well cover the use of two other substances known when combined to produce the particular substance in question. The two substances may then be said to be an equivalent for the substance claimed but this is a use of the word which differs from its ordinary use where the doctrine of equivalents is concerned.

Being of opinion that every claiming clause of Marconi's patent of 1900 is a claim for an entirely novel combination producing an entirely new and useful result and that the use of a two coil transformer is no essential part of his invention, I hold that the defendants, who in my opinion have taken all the essential parts of the invention, are infringers notwithstanding they have substituted an auto-transformer for a transformer in the combination claimed and notwithstanding that the use of an auto-transformer [fol. 2198] with an air core for any such purpose as that for which Marconi has used the transformer may have been new.

The action, therefore, in my opinion succeeds.

Mr. Gray: There are several matters I have to ask your Lordship about, first of all there are two other patents; of course, they are minor matters.

Mr. Colfax: I do not know about that.

Mr. Gray: I mean as compared with this one. Both sides agree that at present we are not prepared to try them, if your Lordship will give us leave to apply later. Will your Lordship give me a certificate that the validity of the patent has come in question and a certificate that the breaches are reasonable and proper. As regards the costs I am going to ask your Lordship to say that the costs should be on the higher scale and that your Lordship should allow three counsel. I think if ever there was a case for it this is the one. It has been done in previous cases.

Mr. Justice Parker: I generally do not give costs on the higher scale unless it is a case in which a lot of experiments were necessary.

Mr. Gray: There were a good many experiments in the first instance by the defendants, it saved the plaintiffs from

putting forward experiments afterwards, no doubt. I submit this is eminently one of the cases where the higher scale costs should be allowed. It has been done in many cases before.

Mr. Justice Parker: Has it been done in any but chemical cases?

Mr. Gray: Yes, in the *Dunlop Pneumatic Tire Company, Limited, v. Wapshare Tube Company, Limited*. That was with respect to tires, a very much simpler matter than this, before Mr. Justice Buckley, as he then was, and he allowed three counsel. It has been done in other cases besides.

Mr. Colfax: There is one fact which will not have escaped your Lordship with reference to the application for three counsel, namely, that the defendants fought the action by two counsel only.

Mr. Gray: Perhaps that is one of the reasons why they have failed.

[fol. 2199] Mr. Colfax: That may be, but I suggest there is no necessity why your Lordship should certify for three counsel if one party has conducted the case by two. That is surely sufficient reason why three counsel should not be allowed on the other side. That is one question. With regard to higher scale costs there are certain cases. My learned friend has alluded to one which is generally cited, but I do think this, that in every case what your Lordship is suggesting has been the real ground, namely, that there has been considerable experimental work. I do not think there has been experimental work here at all.

Mr. Gray: Yes.

Mr. Colfax: We had certain experiments conducted here, but that is not experimental investigation.

Mr. Justice Parker: It may be to your advantage to get costs on the higher scale.

Mr. Colfax: It may be ultimately, and that is our hope, if I may say so. However, that is a matter for your Lordship entirely. My learned friend, I think, is not quite entitled to a certificate——

Mr. Gray: I have not quite finished—the breaches so far as they relate to this patent.

Mr. Justice Parker: So far as this patent is concerned I think you are entitled to a certificate as far as the breaches are concerned, and a certificate that the validity of the patent came in issue if you ask for one.

Mr. Gray: Yes.

Mr. Colefax: Subject to one point—I do not know what turns on it—I do not think my friend proved (b) of his particulars.

Mr. Gray: I understand they were all admitted. Is not that so?

Mr. Colefax: It is only a small point, if it has been admitted let the certificate extend to it, I am not certain of it for the moment. That is as to the exhibition at the Physical Society. If it has been admitted, by all means let it extend to it; if not, it ought to come out; it is a very small matter.

Mr. Gray: Will your Lordship give me costs on the higher scale and certify for three counsel?

Mr. Justice Parker: I think myself that it is a case reasonably fit for three counsel; it was a very long and laborious case but I doubt about the costs on the higher scale. [fol. 2200] Mr. Gray: May I read the judgment of Mr. Justice Buckley in the case of *The Dunlop Tire Company v. The Wapshare Tube Company*? It is reported in R.P.C. Volume 17. The judgment is on page 459. Mr. Justice Buckley says: “I have to deal with two matters here, first the question of whether the costs of three counsel should be allowed, and secondly whether the costs should be allowed upon the higher scale. As to the employment of three counsel, I will read what Mr. Justice Fry said in *Kirkwood v. Webster* (Law Reports, 9 Chancery Division, page 239). We all know that Mr. Justice Fry was a Judge who was strict in these matters, and he was not likely to give costs incautiously. *Kirkwood v. Webster* was a case of fraud. The principle is stated in these words. He says: ‘Though I feel, as other Judges have done, that in cases of this kind I ought not, without very strong reasons, to differ from the conclusion of the Taxing Master, I must in the present case dissent from his conclusion and hold that the defendant was entitled to employ three counsel. I think that the case falls within the rule laid down by Lord Justice Turner in *Pearce v. Lindsay*, and that it was essentially necessary for the purpose of doing justice that three counsel should be employed. I do not speak of a physical or a mathematical necessity, but I think that the case was one in which a reasonable and prudent man, acting with ordinary prudence, would not have ventured to come into court without three counsel.’ It appears to me that what I have to consider is whether this case is one in which a reasonable

and prudent man, acting with ordinary prudence, would not have ventured to come into court without three counsel. In that I disregard altogether the probability that one counsel would be absent at some time during the trial. It is the duty of counsel to attend to their cases throughout, if circumstances will allow. I do not think that three counsel ought ever to be allowed on the ground that somebody may be away. The only test I have to apply is whether, assuming all three counsel will be here all the time, a reasonable and prudent person would have employed three counsel. I think he would."

Mr. Colefax: Your Lordship sees upon that case your Lordship has to find that the defendants were imprudent in coming into court with only two counsel if that test be applied.

Mr. Gray: That is only dealing with the question of three counsel. May I go on with the part as to costs? "The [fol. 2201] other question is whether the costs ought to be taxed on the higher scale. There the rule is this: 'The higher scale may be allowed if, on special grounds arising out of the nature and importance or the difficulty or urgency of the case, the Court or the Judge, shall at the trial or hearing or further consideration,' and so on, 'think that such allowance ought to be so made upon such special grounds as aforesaid.' What I have to say is whether in my judgment, exercised to the best of my discretion, there were here special grounds arising out of the nature and importance of the case. Now, Lord Justice Cotton in the case of *Ellington v. Clark* seems to have laid this down. I do not say that this is a general or inflexible rule, but as regards that case he said: 'When the plaintiffs brought scientific witnesses, it was necessary for the defendants to bring scientific witnesses, and in such a case we think costs ought to be allowed on the higher scale.' I do not in the least understand the learned Lord Justice to say that if the plaintiff chooses to call scientific witnesses the costs ought to be always allowed on the higher scale. The question must be whether the scientific witnesses are really wanted. I then ask myself this question: Was scientific evidence in this case wanted? I cannot doubt it for a moment. The questions I have had to consider have been very complicated questions of mechanics, on which very skilled persons have had very great difficulty in arriving at a conclusion. I think

that the case is one in which, upon special grounds, the costs ought to be allowed upon the higher scale."

Mr. Justice Parker: I have considered it once or twice before, and the conclusion I came to myself in these chemical cases where I will say a great amount of out of court work is required in experiments and otherwise in order to enable the scientific witnesses to give their evidence, that is a case for costs on the higher scale, but I have never done it myself in a purely mechanical case or in an electrical case.

Mr. Gray: This was done in the Dunlop case. It was purely a question of tires and complicated questions of mechanics arose there: and here there are electricity and mechanics as well.

Mr. Justice Parker: I think I will certify that it was a proper case for three counsel, but give costs on the ordinary scale. Nowadays you get your scientific witnesses always allowed.

[fol. 2202] Mr. Gray: Of course, as there are two other patents, there would usually be only one order. I do not know whether your Lordship will allow a separate order to be drawn up on this?

Mr. Justice Parker: The order can be drawn up on this, and I will direct the rest of the trial to stand over.

Mr. Colefax: That is one of the matters I want to address your Lordship upon.

Mr. Gray: I ask your Lordship to say that the plaintiffs shall have the costs of this action except so far as increased by the two other patents which are much less important matters. This was the main patent; the other part of the action is merely as to part of the apparatus, one the spark gap and the other the detector, a very small part of the whole system.

Mr. Justice Parker: I think before this came into court, it was arranged that one patent should be tried.

Mr. Gray: The other two patents were to be considered later or at all events to stand over for further consideration.

Mr. Justice Parker: You are entitled to your full costs except any additional costs there may be in having put the other patents in, and I will direct the rest of the case to stand over, with liberty to apply.

Mr. Gray: If your Lordship pleases.

Mr. Justice Parker: That would be the right form, I think, Mr. Colefax, would not it?

Mr. Colefax: I do not quite follow what that means. Is my friend going to abandon the other two patents or not?

Mr. Gray: No.

Mr. Colefax: Either he abandons the other two patents, in which case we get judgment, or he does not.

Mr. Justice Parker: No. I think the arrangement was, after I had given my judgment in this case, the matter was to stand over that the parties might consider.

Mr. Colefax: If your Lordship pleases. I am quite content with that.

Mr. Justice Parker: If I let the matter go over with liberty to apply, that will be sufficient.

Mr. Colefax: If your Lordship pleases, I am quite content with that. There must be no execution in respect of the [fol. 2203] costs upon this patent until it is determined whether or not my learned friends' clients are going on on the other two patents, because of course it is perfectly obvious we have a set-off for costs if they abandon the other two.

Mr. Gray: We never suggested that we were going to abandon the other two.

Mr. Colefax: Then it is quite clear it cannot be suggested you can draw up an order on which you are to proceed to execution in respect of the costs of this patent.

Mr. Gray: I submit so.

Mr. Colefax: No, that is the point I desire to submit to your Lordship, that that would not be right at all. If my friends are going on on the other two patents and they fail, the costs in the other two may in fact amount even to more than the costs on this. I do not say whether they will or will not; they are quite serious questions raised. It is all very well for my friend to say they are trivial patents, they have not assumed that aspect in the few words that have been said about them by Mr. Astbury. It would not be right that we should be forced to pay costs on this patent until they determine what they are going to do on the other two. If they are not going on, we get certain costs which will be set off. If they are going to fight them, we may get costs enough to wipe out anything on this patent. In any case it would not be right, I submit, that there should be execution in respect of the judgment on this patent until the other two patents are dealt with. Either they abandon them, or your Lordship hears the case on them.

Mr. Justice Parker: I do not see why not. The idea was this patent should be disposed of and the parties should have an opportunity of appealing and carrying it if they liked to the highest tribunal of the land separately.

Mr. Gray: That is so.

Mr. Colefax: I have not appreciated that in any case.

Mr. Justice Parker: It was really to be treated as a separate action on this patent.

Mr. Colefax: What I did understand was there was to be an opportunity for the plaintiffs to consider whether they would go on with the other two or not, but I never understood that the suggestion was that this action should remain [fol. 2204] in abeyance with respect to the other two patents pending an appeal which might go to the House of Lords on this patent, I never understood that. I do not think that is the arrangement between the parties.

Mr. Justice Parker: I think you will find there is a reference to it in the shorthand notes.

Mr. Colefax: I am quite aware it was suggested that they should have time to consider whether they would go on with the other two, but I think that is the whole length that it went—it was not intended to go straight on.

Mr. Justice Parker: It was intended that the order should be drawn up and appealed, before, necessarily, the other cases came on; they were to be so far treated as separate actions if you could do that.

Mr. Colefax: I am not aware of the passage on the shorthand notes, I may be wrong about that.

Mr. Gray: I really understood that if the plaintiffs succeeded on this patent it would not matter in the least about the other two patents to the defendants, because they cannot use their system. I understand it was on that principle that the matter was left.

Mr. Colefax: I can certainly say we never have taken that line at all, because that is not in accordance with the facts. Would your Lordship allow this matter to stand over to be looked into? I will look into the shorthand notes. My learned friend Mr. Terrell is not here; he may have made some arrangement which I am not aware of; what your Lordship suggests is not my understanding of the arrangement.

Mr. Justice Parker: No, I think the proper course is to give judgment on this patent, and let the rest stand over.

Mr. Colefax: Then there is one other matter.

Mr. Justice Parker: It certainly was not within my view that the order should not be drawn up until the other patents were disposed of; if I had thought that I should probably have insisted on hearing all the patents together. I was told that if this patent was proceeded with only, and an order drawn up so that the parties could appeal it, very likely the others would never be heard of at all.

Mr. Colefax: I am not questioning your Lordship's recollection, but I have not that in mind myself.

There is one other matter; would your Lordship stay the injunction if we give notice of appeal, say, within 14 or 10 [fol. 2205] days? That, I submit, would be right. Why I mention it is this. I understand that there is apparatus on ships for which conceivably we may still be responsible; there is some difficulty in getting that apparatus off those ships. I should suggest no harm could be done if the injunction was stayed.

Mr. Justice Parker: So far as the injunction is concerned, what do you say, Mr. Gray, to staying it?

Mr. Gray: I am afraid the plaintiffs will not agree to that. If there are particular circumstances as to one or two boats that the defendants are in a difficulty about, I do not think the plaintiffs will be harsh; but subject to that, I submit that the injunction should go.

Mr. Colefax: It is obvious that, supposing that we should succeed ultimately, we have in the meantime, if the injunction is to go, to pull off certain apparatus from certain ships.

Mr. Gray: That is the common practice in all cases where the defendant gets judgment against him.

Mr. Justice Parker: I do not see why you should have a stay of execution with regard to fresh sales; but, if it is a question of getting apparatus off ships, perhaps it would be convenient to leave the things on board the ships where there has been an installation.

Mr. Gray: I ask your Lordship to let the injunction go at once; the plaintiffs will consider any special case in which the defendants find a difficulty. I ask your Lordship not to stay the injunction.

Mr. Colefax: I ask your Lordship to stay the injunction except insofar as future sales are concerned. I ask your Lordship not to allow the injunction in respect of user of apparatus already installed, pending the Appeal.

Mr. Gray: Difficulties always do occur when a defendant infringes on account of some contract he is carrying out, but I have never heard that put forward as a ground for a stay.

Mr. Justice Parker: It is put forward. I think the proper thing to do would be, if notice of appeal is served within ten days, did you say—

Mr. Colefax: I said 14.

Mr. Justice Parker: If notice of appeal is served within 14 days, I think the operation of the injunction ought to be suspended during the appeal, so far as it affects the user of any instrument already installed by them on board ship. [fol. 2206] Mr. Collax: If your Lordship pleases; that is all I am asking.

Mr. Gray: The injunction against the use is a different thing; this injunction only operates as regards the defendants supplying apparatus to any other boat.

Mr. Justice Parker: It will not be suspended as regards that.

Mr. Gray: The users are not the defendants.

Mr. Colefax: You are forgetting; that may or may not be so.

Mr. Justice Parker: There are two ends.

Mr. Colefax: The apparatus may still be ours. If your Lordship says that, that will satisfy me.

Mr. Justice Parker: I think that will be reasonable. That will not justify you in installing a lot more.

Mr. Colefax: No, my Lord, I entirely appreciate that. I was not asking in respect to future installations.

Mr. Justice Parker: Then it will be an ordinary judgment in the action on this particular patent, and the cost will be costs of the whole action except so far as increased by the joining in the action of the other patents.

Mr. Gray: If your Lordship pleases.

Mr. Justice Parker: The rest of the action as to the other patents is to stand over generally, with liberty to either party to apply.

Mr. Gray: If your Lordship pleases.

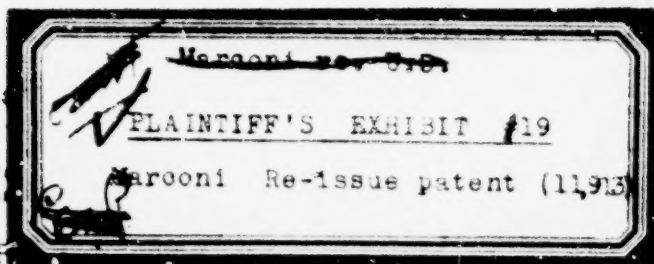
Mr. Justice Parker: What do you want in the shape of relief besides an injunction—anything?

Mr. Gray: Two certificates, and delivery up. Of course, the delivery up will equally stand so far as anything that

UNITED STATES

DEPARTMENT OF

UNITED STATES PATENT OFFICE



To all to whom these presents shall come, Greeting.

THIS IS TO CERTIFY that the annexed is a true copy from the Records

of this Office of the

Reissue Letters Patent of

Guglielmo Marconi, Assignor, by mesne assignments, to

Marconi's Wireless Telegraph Company, Limited,

Number 11,913,

Granted June 4, 1901,

for

Improvement in Transmitting Electrical Impulses and Signals and Apparatus

Therefor.

IN TESTIMONY WHEREOF I have hereunto set my hand

and caused the seal of the Patent Office to be affixed

at the City of Washington, this 23rd day

of September, in the year of our Lord one

thousand nine hundred and sixteen and of

the Independence of the United States of America the

one hundred and forty-first.



6-1022

*F. W. H. Clay*  
Acting Commissioner of Patents

2207

No. 11,913.

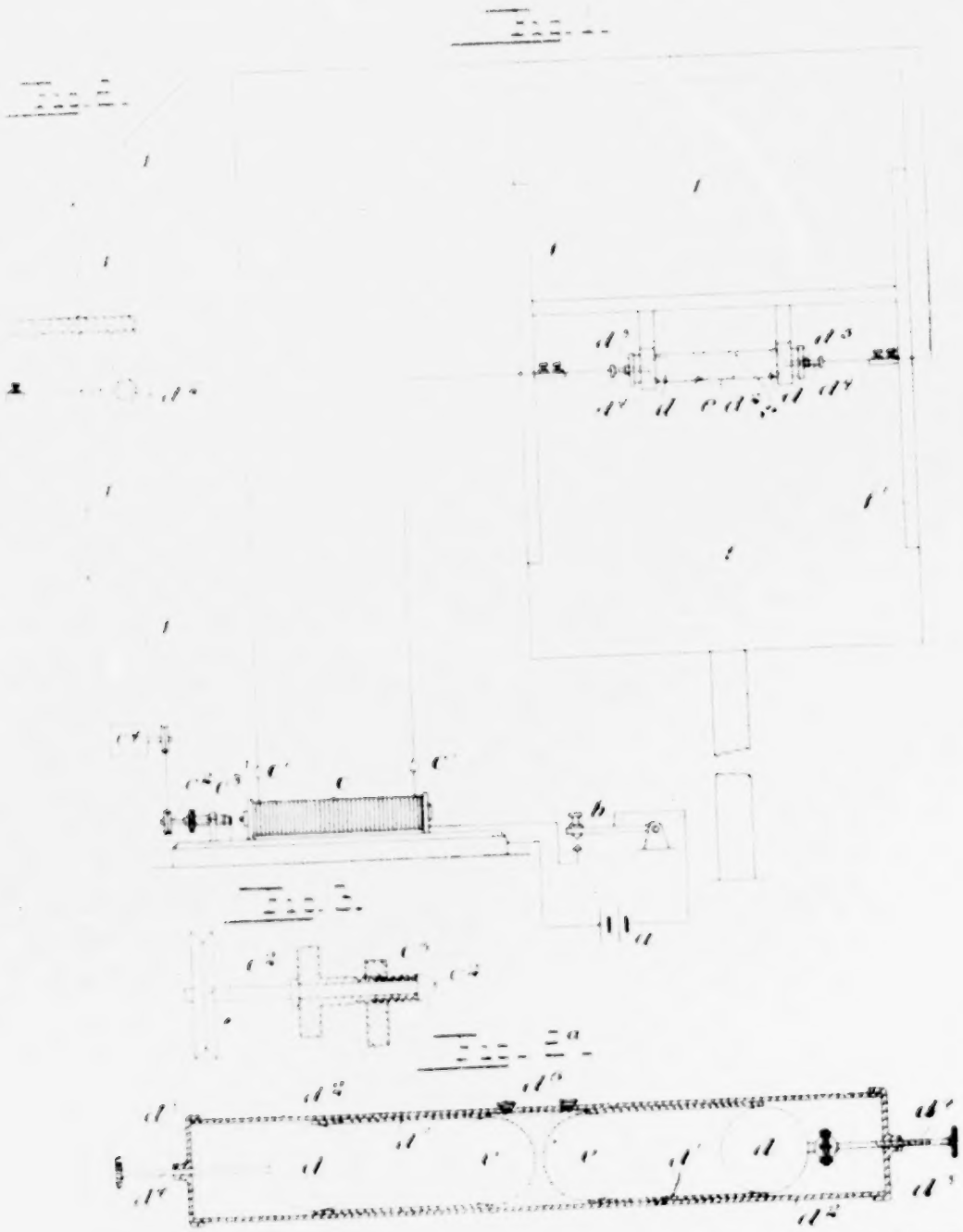
Reissued June 4, 1901.

G. MARCONI.

TRANSMITTING ELECTRICAL IMPULSES AND SIGNALS AND APPARATUS THEREFOR.

Approved Dec. 1, 1901.

3 Sheets—Sheet 1.



WITNESSES

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TRANSMITTING ELECTRICAL IMPULSES AND SIGNALS AND APPARATUS THEREFOR

Application filed Apr. 2, 1901

3 Sheets—Sheet 2

Fig. 4.

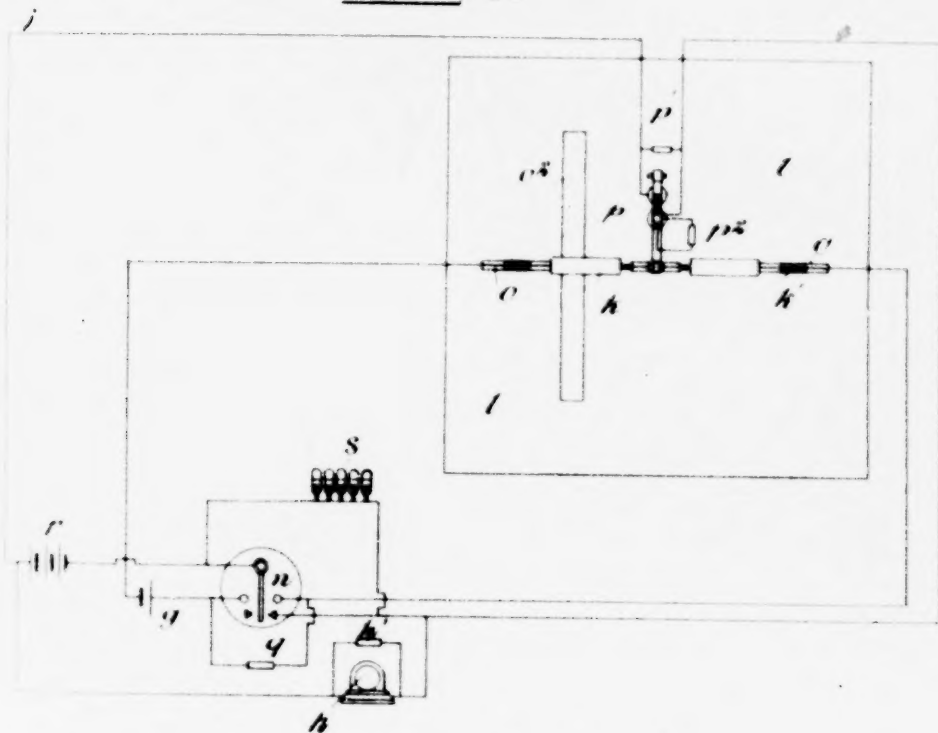


Fig. 5.

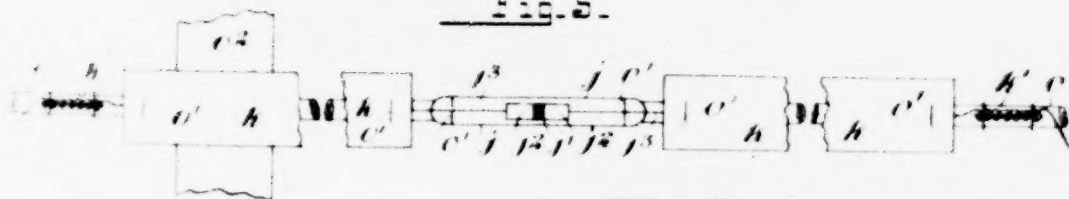


Fig. 6.

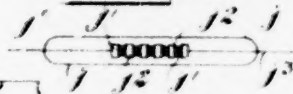
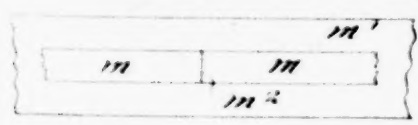


Fig. 7.



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Application filed Apr. 1, 1901.

3 Sheets - Sheet 3.

Fig. 9.



Fig. 10.

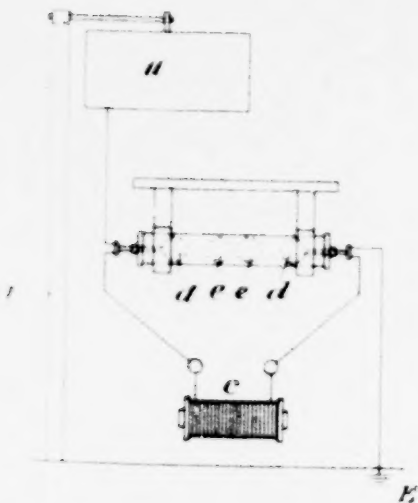
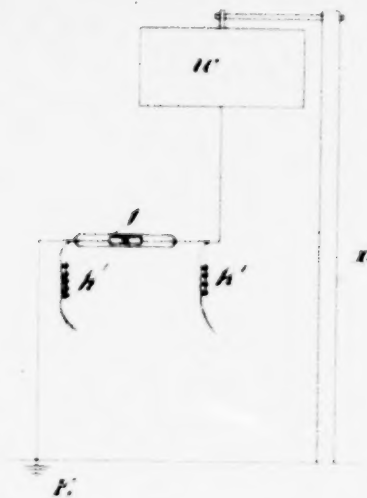


Fig. 11.



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# UNITED STATES PATENT OFFICE.

GUGLIELMO MARCONI, OF LONDON, ENGLAND, ASSIGNOR, BY MESNE ASSIGNMENTS, TO MARCONI'S WIRELESS TELEGRAPH COMPANY, LIMITED, OF ENGLAND.

TRANSMITTING ELECTRICAL IMPULSES AND SIGNALS AND APPARATUS THEREFOR.

SPECIFICATION forming part of Reissued Letters Patent No. 11,913, dated June 4, 1901.

Original No. 586,193, dated July 13, 1897. Application for reissue filed April 1, 1901. Serial No. 53,896.

*To all whom it may concern:*

Be it known that I, GUGLIELMO MARCONI, a subject of the King of Italy, residing and having a post-office address at 18 Finch Lane, Threadneedle street, London, England, have invented certain new and useful Improvements in Transmitting Electrical Impulses and Signals and in Apparatus Therefor, of which the following is a specification.

According to this invention electrical signals, actions, or manifestations are transmitted (through the air, earth, or water) by means of oscillations of high frequency, such as have been called "Hertz rays" or "Hertz oscillations." All line-wires may be dispensed with. At the transmitting-station I preferably employ a Ruhmkorff coil having in its primary circuit a Morse key or other signaling instrument and at its poles appliances for producing the desired oscillations. The Ruhmkorff coil may, however, be replaced by any other source of high-tension electricity. When working with large amounts of energy, it is, however, better to keep the coil or transformer constantly working for the time during which one is transmitting, and instead of interrupting the current of the primary interrupting the discharge of the secondary. In this case the contacts of the key should be immersed in oil, as otherwise, owing to the length of the spark, the current will continue to pass after the contacts have been separated. At the receiving-station there is a local-battery circuit containing any ordinary receiving instrument and an appliance for closing the circuit, the latter being actuated by the oscillations from the transmitting-station. When transmitting through the air, and it is desired that the signal should only be sent in one direction, I place the oscillation-producer at the transmitting-station in the focus or focal line of a reflector directed to a receiving station, and I place the circuit-closer at the receiving-station in a similar reflector directed toward the transmitting-station. When transmitting signals by the aid of earth connections, I connect one end of the oscillation-producer and one end of the circuit-closer to earth and the other ends to plates prefer-

ably electrically tuned with each other in the air and insulated from earth.

Figure 1 is a diagrammatic front elevation of the instruments at the transmitting-station when signaling through the air, and Fig. 2 is a vertical section of the transmitter. Fig. 2<sup>a</sup> is a longitudinal section of the oscillator to a larger scale. Fig. 3 shows a detail of the trembler-break on a larger scale. Fig. 4 is a diagrammatic front elevation of the instruments at the receiving-station. Fig. 5 is an enlarged view of the receiver. Fig. 6 shows a modification of the tube *j*. Fig. 7 shows the detector. Fig. 8 is a full-sized view of the liquid resistance. Figs. 9 and 10 show modifications of the arrangements at the transmitting-station. Fig. 11 shows a modification of the arrangements at the receiving-station.

Referring now to Fig. 1, *a* is a battery, and *b* an ordinary Morse key closing the circuit through the primary of a Ruhmkorff coil *c*. The terminals *c'* of the secondary circuit of the coil are connected to two metallic balls *d d*, fixed by heat or otherwise at the ends of tubes *d' d'*, Fig. 2<sup>a</sup>, of insulating material, such as ebonite or vulcanite. *e e* are similar balls fixed in the other ends of the tubes *d'*. The tubes *d* fit tightly in a similar tube *d''*, having covers *d''*, through which pass rods *d'*, connecting the balls *d* to the conductors. One (or both) of the rods *d'* is connected to the ball *d* by a ball-and-socket joint and has a screw-head upon it working in a nut in the cover *d''*. By turning the rod, therefore, the distance of the balls *e* apart can be adjusted. *d'* represents holes in the tube *d''*, through which vaseline, oil, or like material is introduced into the space between the balls *e*.

The balls *d* and *e* are preferably of solid brass or copper, and the distance they should be apart depends on the quantity and electromotive force of the electricity employed, the effect increasing with the distance so long as the discharge passes freely. With a coil giving an ordinary eight-inch spark, the distance between *e* and *e* should, to assure good results, be from one twenty-fifth to one-thirtieth of an inch and the distance between *d* and

about one and one-half inches. Other conditions being equal, the larger the balls the greater is the distance at which it is possible to communicate. I have generally used balls of solid brass of four inches diameter, giving oscillations of ten inches length of wave.

If a very powerful source of electricity giving a very long spark be employed, it is preferable to divide the spark gap between the central balls of the oscillator into several smaller gaps in series. This may be done by introducing between the big balls smaller ones of about half an inch diameter, held in position by ebonite frames.

I find that the regularity and power of the discharge of an ordinary Ruhmkorff coil with a trembler-break on its primary is greatly improved by causing one of the contacts of the vibrating break to revolve rapidly. I do this preferably by having a revolvable central core  $c^2$ , Fig. 3, in an ordinary screw  $c^3$ , which is in communication with platinum contacts. I cause the said central core, with one of the platinum contacts attached to it, to revolve, preferably, by connecting it to a small electric motor  $c^4$ . This motor can be worked by the same circuit that works the coil or, if necessary, by a separate circuit. The connections are not shown in the drawings. By this means the platinum are kept smooth and any tendency to stick is removed. They last, also, much longer. At the receiving station is a battery whose circuit includes an ordinary telegraphic instrument (or it may be a relay or other apparatus which it is desired to work from a distance) and a circuit-closer.

In Fig. 4,  $g$  is the battery, and  $h$  a telegraphic instrument on the derived circuit of a relay  $n$ .

The appliance I employ as a circuit-closer is shown at Fig. 5, and consists of a glass tube  $j$ , containing metallic powder or grains of metal  $j^1$ , each end of the column of powder being connected to a metallic plate  $k$  of suitable length to cause the system to resonate electrically in unison with the electrical oscillations transmitted. The glass tube may be replaced in some places by one of gutta-percha or like material. Two short pieces  $j^2$ , preferably of thick silver wire of the same diameter as the internal diameter of the tube  $j$ , so as to fit tightly in it, are joined to two pieces of platinum wire  $j^3$ . The tube is closed and sealed onto the platinum wires  $j^3$  at both ends.

Many metals can be employed for producing the powder or filings  $j^1$ , but I prefer to use a mixture of two or more different metals. I find hard nickel to be the best metal, and I prefer to add to the nickel filings about ten per cent. of hard-silver filings, which increase greatly the sensitiveness of the tube to electric oscillations. By increasing the proportion of silver powder or grains the sensitiveness of the tube also increases; but it is better for ordinary work not to have a tube of too great sensitiveness, as it might be influ-

enced by atmospheric or other electricity. The sensitiveness can also be increased by adding a very small amount of mercury to the filings and mixing up until the mercury is absorbed.

The mercury must not be in such a quantity as to clot or cake the filings. An almost imperceptible globule is sufficient for a tube. Instead of mixing the mercury with the powder one can obtain the same effects by slightly amalgamating the inner surfaces of the plugs which are to be in contact with the filings. Very little mercury must be used, just sufficient to brighten the surface of the metallic plugs without showing any free globules. The size of the tube and the distance between the two metallic stops may vary under certain limits. The greater the space allowed for the powder the larger and coarser ought to be the filings or grains.

I prefer to make my sensitive tubes of the following size: The tube  $j$  is one and one-half inches long and one-tenth or one-twelfth of an inch in internal diameter. The length of the stops  $j^2$  is about one-fifth of an inch, and the distance between the stops is about one-thirtieth of an inch. I find that the smaller the space between the stops in the tube the more sensitive it proves; at the space cannot under ordinary circumstances be excessively shortened without injuring the fidelity of the transmission.

The metallic powders ought not to be fine, but, rather, as coarse as can be produced by a large and rough file.

All the very fine powder ought to be removed by blowing or sifting.

The powder ought not to be compressed between the stops, but, rather, loose and in such a condition that when the tube is tapped the powder may be seen to move.

The tube must be sealed; but a vacuum inside it is not essential. A slight vacuum, however, results from having heated it while sealing it. Care must also be taken not to heat the tube too much in the center when sealing it, as it would oxidize the surfaces of the silver stops and also the powder, which would diminish its sensitiveness. I use in sealing the tubes a hydrogen and air flame. A vacuum is, however, desirable, and I have used one of about one one-thousandth of an atmosphere, obtained by a mercury-pump. It is also necessary for the powder or grains to be dry and free from grease or dirt, and the files used in producing the same ought to be frequently washed and dried and used when warm.

If the tube has been well made, it should be sensitive to the induction of an ordinary electric bell when the same is working at one to two yards or more from the tube.

In order to keep the sensitive tube  $j$  in good working order, it is desirable, but not absolutely necessary, not to allow more than one milliampere to flow through it when active. If a stronger current is necessary, several

tubes may be put in derivation between the tuned plates; but this arrangement is not quite as satisfactory as the single tube. It is necessary when using tubes of the type I have described not to insert in the circuit more than one coil of the Leclanche type, as a higher electromotive force than 1.5 volts is apt to pass a current through the tube even when no oscillations are transmitted. I can, however, construct tubes capable of working with a much higher electromotive force. Fig. 6 shows one of these tubes. In this tube instead of one space or gap filled with filings there are several spaces separated by sections of tight-fitting silver wire. A tube thus constructed, observing also the rules of construction of my tubes in general, will work satisfactorily if the electromotive force of the battery in circuit with the tube is equal to 1.2 volts multiplied by the number of gaps. With this tube, also, it is well not to allow a current of more than one milliampere to pass.

The tube *j* may be replaced by other forms of imperfect electrical contacts.

The plates *k* are of copper or aluminium or other metal, about half an inch or more broad, about one-fiftieth of an inch thick, and preferably of such a length as to be electrically tuned with the electric oscillations transmitted. The means I adopt for fixing the length of the plates is as follows: I stick a rectangular strip of tin-foil *m* (see Fig. 7) about twenty inches long, (the length depends on the supposed length of wave that one is measuring,) by means of a weak solution of gum, onto a glass plate *m'*. Then by means of a very sharp penknife or point I cut across the middle of the tin-foil, leaving a mark of division *m*<sup>2</sup>. If this detector is held in the proximity (four or five yards) and parallel with the axis of the oscillator in action it will show little sparks at *m*<sup>2</sup>. If the length of the pieces of tin-foil approximates to the length of wave emitted from the oscillator, the spark will take place between them at a certain distance from the transmitter, which is a maximum when they are of suitable length. By shortening or lengthening the strips, therefore, it is easy to find the length most appropriate to the length of wave emitted by the oscillator. It is desirable to try this detector in the focus or focal line of the reflector. The length so found is the proper length for the plates *k*, or rather these should be about half an inch shorter on account of the length of the sensitive tube *j*, connected between them.

Instead of the tuned plates *k* tubes or even wires may be employed.

*f* is a cylindrical parabolic reflector made by bending a metallic sheet, preferably of brass or copper, to form and fixing it to metallic or wooden ribs *f'*.

*l* is a cylindrical parabolic reflector similar to that used at the transmitting-station.

The reflectors applied to the receiver and transmitter ought to be, preferably, in length

and opening the double at least of the length of wave emitted from the oscillator.

It is slightly advantageous for the focal distance of the reflector at the receiving-station to be equal to one-fourth or three-fourths of the wave length of the oscillation transmitted.

I have hitherto only mentioned the use of cylindrical reflectors; but it is also possible to use ordinary concave reflectors, preferably parabolic, such as are used for projectors.

It is not essential to have a reflector at the transmitters and receivers; but in their absence the distance at which one can communicate is much smaller.

When no oscillations are sent from the transmitting-station, the tube *j* does not conduct the current and the local-battery circuit is broken; but when the powder or tube is influenced by the electrical oscillations from the transmitter it conducts and closes the circuit. I find, however, that when once started the powder in the tube continues to conduct even when the oscillations from the transmitter have ceased; but if it be shaken or tapped the circuit is broken. A tube well prepared will instantly interrupt the current passing through it at the slightest tap, provided it is inserted in a circuit in which there is little self-induction and small electromotive force, such as a single cell, and where the effects of self-induction have been removed by one of the methods which I will presently describe.

The two plates *k* communicate with the local circuit through two very small coils *k'*, which I will call "choking-coils," formed by winding a few inches of very thin and insulated copper wire around a bit of iron wire about an inch and a half long. The object of these choking-coils is to prevent the high-frequency oscillation induced across these plates by the transmitter from dissipating itself by running along the local-battery wires, which might weaken its effect on the sensitive tube *j*. These choking-coils may, however, be sometimes replaced by simple thin wires. They may also be connected directly to the tube *j*. The local circuit in which the sensitive tube *j* is inserted contains a sensitive relay *n*, preferably wound to a resistance of about twelve hundred ohms. This resistance need not be necessarily that of the relay, but may be the sum of the resistance of the relay and another additional resistance. The relay ought to be one possessing small self-induction.

The plates *k*, tube *j*, and coils *k'* are fastened by means of wire stitches *o* to a thin glass tube *o*, preferably not longer than twelve inches, firmly fixed at one end to a strong piece of timber *o*<sup>1</sup>. This may be done by means of wood or ebonite grasping-screws.

I do the tapping automatically by the current started by the tube, employing a trembler *p* on the circuit of the relay *n* similar in construction to that of an electric bell, but having a shorter arm. This vibrator must

be carefully adjusted. Preferably the blows should be directed slightly upward to prevent the filings from getting caked. In place of tapping the tube, the powder can be disturbed by slightly moving outward and inward one or both of the stops  $j^2$ , the trembler  $p$  being replaced by a small electromagnet (or magnets) whose armature is connected to the stop.

I ordinarily work the telegraphic receiver  $h$  (or other instruments) by a derivation, as shown, from the circuit which works the trembler  $p$ . They can also, however, be worked in series with the trembler. When working ordinary sounders or Morse apparatus, a special adjustment of the same is sometimes needed to enable one to obtain dots and dashes. Sometimes it is necessary to work the telegraphic instruments or relays from the back stops of the first relay, as is done in some systems of multiple telegraphy. Such adjustments are known to telegraphic experts.

By means of a tube with multiple gaps it is possible to work the trembler and also the signaling or other apparatus direct on the circuit which contains the tube; but I prefer, when possible, to work with the single-gap tube and the relay, as shown. With a sensitive and well-constructed trembler it is also possible to work the trembler with the single-gap tube in series with it without the relay.

In derivation on the terminals of the relay  $n$  is placed an ordinary platinoid resistance double-wound (or wound on the "bight," as it is sometimes termed) coil  $q$  of about four times the resistance of the relay, which prevents the self-induction of the winding of the relay from affecting the sensitive tube.

The circuit actuated by the relay contains an ordinary battery  $r$  of about twelve cells and the trembler  $p$ , the resistance of the winding of which should be about one thousand ohms, and the core ought preferably to be of soft iron, hollow and split lengthwise, like most electromagnets used in telegraph instruments. In series or derivation from this circuit is inserted the telegraphic or other apparatus  $h$  which one may desire to work. It is desirable that this instrument or apparatus if on a derivation should have a resistance equal to the resistance of the trembler  $p$ . A platinoid resistance  $h'$  of about five times the resistance of the instrument is inserted in derivation across the terminals of the instrument and connected as close to the same as possible. In derivation across the terminals of the trembler  $p$  is placed another platinoid resistance  $p'$ , also of about five times the resistance of the trembler. A similar resistance  $p^2$  is inserted in a circuit connecting the vibrating contacts of the trembler. In derivation across the terminals of the relay-circuit it is well to have a liquid resistance  $s$ , which is constituted of a series of tubes, one of which is shown full size in Fig. 8 filled with water

acidulated with sulfuric acid. The number of these tubes in series across the said terminals ought to be about ten for a circuit of fifteen volts, so as to prevent, in consequence of their counter electromotive force, the current of the local battery from passing through them, but allowing the high-tension jerk of current generated at the opening of the circuit in the relay to pass smoothly across them without producing perturbing sparks at the movable contact of the relay. It is also necessary to insert a platinoid resistance in derivation on any apparatus one may be working on the local circuits. These resistances ought also to be inserted in derivation on the terminals of any resistance which may be apt to give self-induction.

I find it convenient when transmitting across long distances to make use of the transmitter shown in Fig. 9.

There are two poles connected by a rope  $l'$ , to which are suspended, by means of insulating-suspenders, two metallic plates  $l^2$ , preferably in the form of cylinders closed at the top, connected to the spheres  $e$  (in oil or other dielectric, as before) and to the other balls  $f$  in proximity to the spheres  $c'$ , in communication with the coil or transformer  $c$ . The balls  $f$  are not absolutely necessary, as the plates  $l^2$  may be made to communicate with the coil or transformer by means of thin insulated wires. The receiver I adopt with this transmitter is similar to it, except that the spheres  $e$  are replaced by the sensitive tube  $j$  and plates  $k$ , while the spheres  $f$  are replaced by the choking-coils  $k'$ , in communication with the local circuit. It may be observed that, other conditions being equal, the larger the plates at the transmitter and receiver and the higher they are from the earth and to a certain extent the farther apart they are the greater is the distance at which correspondence is possible.

When transmitting with connections to the earth or water, I use a transmitter as shown in Fig. 10. I connect one of the spheres  $d$  to earth  $E$ , preferably by thick wire, and the other to a plate or elevated conductor  $u$ , carried by a pole  $v$  and insulated from earth, or the spheres  $d$  may be omitted and one of the spheres  $e$  be connected to earth and the other to the plate or conductor  $u$ . At the receiving-station, Fig. 11, I connect one terminal of the sensitive tube  $j$  to earth  $E$ , also by a thick wire, and the other to a plate or elevated conductor  $w$ , preferably similar to  $u$ . The plate  $w$  may be suspended on a pole  $x$  and must be insulated from earth. The larger the plates of the receiver and transmitter and the higher from the earth the plates are carried the greater is the distance at which it is possible to communicate. When using the last-described apparatus, it is not necessary to have the two instruments in view of each other, as it is of no consequence if they are separated by mountains or other obstacles. At the receiver it is possi-

ble to pick up the oscillations from the earth or water without having the plate *or*. This may be done by connecting the terminals of the sensitive tube / to two earths preferably at a certain distance from each other and in a line with the direction from which the oscillations are coming. These connections must not be entirely conductive, but must contain a condenser of suitable capacity—say one square yard of surface. Balloons can also be used instead of plates on poles provided they carry up a plate or are themselves made conductive by being covered with tin-foil. As the height to which they may be sent is great, the distance at which communication is possible becomes greatly multiplied. Kites may also be successfully employed, if made conductive by means of tin-foil.

The apparatus above described is so sensitive that it is essential either that the transmitters and receivers at each station should be at a considerable distance from each other or that they should be screened from each other by stout metal plates. It is sufficient to have all the telegraphic apparatus in a metal box and any exposed part of the circuit of the receiver inclosed in metallic tubes which are in electrical communication with the box. Of course the part of the apparatus which has to receive the radiation from the distant station must not be inclosed, but possibly screened from the local transmitter by means of metallic sheets. When working through the earth or water, the local receiver must be switched out of circuit when the transmitter is at work, and this may also be done when working through air.

The operation of my apparatus and system of communication or signals is as follows: The Ruhmkorff coil or other source of high tension electrically capable of producing Hertz oscillations being in circuit with a signaling instrument—such as a Morse key, for instance—the operator by closing the circuit in the way commonly employed for producing dots and dashes in ordinary telegraphy will cause the oscillator to produce either a short or a more prolonged electric discharge or spark or succession of sparks, and this will cause a corresponding short or more prolonged oscillation in the surrounding medium corresponding in duration to the short or longer electrical impulse which in ordinary telegraphy produces a dot or dash. Such oscillations of defined character will thereupon be propagated as such throughout the medium and will affect a properly-constructed instrument at a distant receiving-station. At such station the imperfect-contact instrument is in circuit with a relay, and when oscillations from the transmitting-station reach and act upon such imperfect contact its resistance is reduced, and the circuit is thereby closed during the continuance of the oscillation and for a length of time corresponding thereto. The closing of the relay-circuit causes the sounder or other signal apparatus to act in

accordance with the particular oscillation received, and the oscillation also immediately starts the action of the shaking or tapping device, which so shakes the powder in the imperfect-contact instrument as to cause it to break circuit as soon as the oscillation ceases which has closed the circuit and produced a movement of the signaling instrument corresponding thereto. I am therefore enabled to communicate signals telegraphically without wires by thus artificially forming oscillations at the transmitting-station into definite signals by means of a signaling instrument and receiving and reading the same at a receiving-station by an imperfect-contact instrument, which when acted upon by such defined oscillations operates, first, to close the circuit in accordance with the received oscillation and produce a corresponding movement of the receiving instrument, relay, or sounder, and also to operate a shaking device to automatically reopen the circuit immediately after the reception of each oscillation, thereby preserving the results of its defined character in the action of the receiver.

All the details specified herein of construction of the sensitive tube and its connections are desirable for great efficiency; but the fundamental features of my system of transmission are not restricted to such details.

I am aware that the sensitiveness of various apparatus, including tubes containing filings, to more or less distant electrical disturbances has been observed in a general way and that it has also been proposed to disturb the conductivity of such filings by various instrumentalities for shaking the tubes containing the same. I am also aware that the use of tubes containing metallic powders of several separate kinds has been described or suggested in connection with certain experiments relating to so-called "coherers," but I am not aware that the utility of a mixture of metallic powders has ever previous to my invention been ascertained and utilized for the purpose of obtaining the required degree of sensitiveness in such an instrument.

I am aware of the publication of Professor Lodge of 1894, at London, England, entitled "*The Work of Hertz*" and the description therein of various instruments in connection with manifestations of Hertz oscillations. I am also aware of the papers by Professor Popof in the *Proceedings of the Physical and Chemical Society of Russia* in 1895 or 1896; but in neither of these is there described a complete system or mechanism capable of artificially producing Hertz oscillations and forming the same into and propagating them as definite signals and capable of receiving and reproducing, telegraphically, such definite signals; nor has any system been described, to my knowledge, in which a Hertz oscillator at a transmitting-station and an imperfect-contact instrument at a receiving-station are both arranged with one terminal

to earth and the other elevated or insulated; nor am I aware that prior to my invention any practical form of self-recovering imperfect-contact instrument has been described.

5 I believe that I am the first to discover and use any practical means for effective telegraphic transmission and intelligible reception of signals produced by artificially-formed Hertz oscillations.

10 What I claim is—

1. In an apparatus for communicating electrical signals by means of a producer of Hertz oscillations, and a signaling instrument, the combination, in the receiver, of an imperfect electrical contact, a circuit through the contact, and a receiving instrument operated by the influence of such oscillations on said contact, substantially as and for the purpose described.

20 2. In an apparatus for communicating electrical signals by means of a producer of Hertz oscillations and a signaling instrument, the combination, in the receiver, of an imperfect electrical contact, a circuit through the contact, and means, controlled by said circuit, operating to shake the contact, substantially as and for the purpose described.

3. The combination, in an apparatus for communicating electrical signals, of a spark-producer at the transmitting-station, an earth connection to one end of the spark-producer, an insulated conductor connected to the other end, an imperfect electrical contact at the receiving-station, an earth connection to one end of the contact, an insulated conductor connected to the other end, and a circuit through the contact, substantially as and for the purpose described.

4. The combination, in an apparatus for communicating electrical signals, of a spark-producer at the transmitting-station, an earth connection to one end of the spark-producer, an insulated conductor connected to the other end, an imperfect electrical contact at the receiving-station, an earth connection to one end of the contact, an insulated conductor connected to the other end, a circuit through the contact, and means, controlled by the circuit, for shaking the contact, substantially as and for the purpose described.

5. The combination, in an apparatus for communicating electrical signals, of a spark-producer at the transmitting-station, an earth connection to one end of the spark-producer, an insulated conductor connected to the other end, an imperfect electrical contact at the receiving-station, choking-coils connected to each end of the contact, an earth connection to one end of the imperfect contact, an insulated conductor connected to the other end, and a circuit through the coils and contact, substantially as and for the purpose described.

6. The combination, in an apparatus for communicating electrical signals by means of a producer of Hertz oscillations, and a signaling instrument, an imperfect electrical

contact at the receiving-station, choking-coils connected to the contact, a circuit through the coils and contact, and means, controlled by the circuit and operating to shake the contact, substantially as and for the purpose described.

7. The combination, in an apparatus for communicating electrical signals by means of a producer of Hertz oscillations and a signaling instrument, an imperfect electrical contact at the receiving-station, means, connected to each end of the contact, to prevent the oscillation from dissipating itself, a circuit through said means and contact, and means controlled by the circuit and operating to shake the contact, substantially as and for the purpose described.

8. The combination, in an apparatus for communicating electrical signals, of a spark-producer at the transmitting-station, an earth connection to one end of the spark-producer, an insulated conductor connected to the other end, a tube containing metallic powder at the receiving-station, an earth connection to the powder and an insulated conductor also connected therewith, and a circuit through the powder, substantially as and for the purpose described.

9. The combination, in an apparatus for communicating electrical signals, of a spark-producer at the transmitting-station, an earth connection to one end of the spark-producer, an insulated conductor connected to the other end, a tube containing metallic powder, and an insulated conductor also connected therewith, a circuit through the powder and means, controlled by the circuit, for shaking the powder, substantially as and for the purpose described.

10. The combination, in an apparatus for communicating electrical signals, of a spark-producer at the transmitting-station, an earth connection to one end of the spark-producer, an insulated conductor connected to the other end, a tube containing metallic powder at the receiving-station, choking-coils connected to the powder, an earth connection to the powder and an insulated conductor also connected therewith, and a circuit through the coils and powder, substantially as and for the purpose described.

11. The combination, in an apparatus for communicating electrical signals, of a producer of Hertz oscillations, electrically connected with a signaling instrument at the transmitting-station, a tube containing metallic powder at the receiving-station, choking-coils connected to the powder, a circuit through the powder, and means, controlled by said circuit, for shaking the powder, substantially as and for the purpose described.

12. The combination, in an apparatus for communicating electrical signals, of a producer of Hertz oscillations, electrically connected with a signaling instrument at the transmitting-station, a tube containing metallic powder at the receiving-station, choking-coils connected to the powder, a circuit through the powder, and means, controlled by said circuit, for shaking the powder, substantially as and for the purpose described.

ing-coils and earth connection through condensers connected to the powder, a circuit through the coils and powder, and means, controlled by the circuit, for shaking the powder, substantially as and for the purpose described.

13. The combination, in an apparatus for communicating electrical signals, of a producer of Hertz oscillations, electrically connected with a signaling instrument at the transmitting-station, a tube containing metallic powder at the receiving-station, electrically-tuned devices connected to the powder, a circuit through the powder, and means, controlled by said circuit, for shaking the powder, substantially as and for the purpose described.

14. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, tuned metallic plates connected to it, a circuit through the contact, and means, controlled by the circuit, for shaking the contact.

15. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, choking-coils connected to the contact, a circuit through the coils and contact, and means, controlled by the circuit, for shaking the contact.

16. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, tuned metallic plates and choking-coils connected to the contact, a circuit through the same, and means, controlled by the circuit, for shaking the contact.

17. In a receiver for electrical oscillations, the combination of a tube containing a mixture of metallic powders, a circuit through the same, and means, controlled by the circuit, for shaking the powder.

18. In a receiver for electrical oscillations, the combination of a tube containing a metallic powder or powders and mercury, a circuit through the same, and means, controlled by the circuit, for shaking the powder.

19. In a receiver for electrical oscillations, the combination of a tube, metallic plugs in the tube, metallic powder between the plugs, metallic plates connected to the plugs, choking-coils connected to the plugs, and a circuit through the coils, plugs and powder.

20. In a receiver for electrical oscillations, the combination of a tube, metallic plugs in the tube, metallic powder between the plugs, metallic plates connected to the plugs, choking-coils connected to the plugs, a circuit through the coils, plugs and powder, and means, controlled by the circuit, for shaking the powder.

21. In a receiver for electrical oscillations, the combination of a tube, metallic plugs in the tube, a mixture of metallic powder and mercury between the plugs, choking-coils connected to the plugs, a circuit through the coils, plugs and powder, and means, controlled by the circuit, for shaking the powder.

22. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, choking-coils connected to the contact, a circuit through the coils and contact, a relay controlled by the circuit, and means, controlled by the relay, for shaking the contact.

23. In a receiver for electrical oscillations, the combination of an imperfect electrical contact, a circuit through the contact, an electric trembler shaking the contact, and means for preventing the self-induction of the trembler from affecting the contact.

24. The combination of a transmitter capable of producing electrical oscillations or rays of definite character at the will of the operator, and a receiver located at a distance and having a conductor tuned to respond to such oscillations, a variable resistance medium in circuit with the conductor, whose resistance is altered by the received oscillations, means, controlled by the received oscillations, for restoring the resistance medium to its normal condition after the reception of such oscillations, and means for rendering the received oscillations manifest.

In witness whereof I have hereunto signed my name, at 18 Finch Lane, in the city of London, the 29th day of January, in the year 1901.

GUGLIELMO MARCONI.

In presence of—

SAMUEL FLOOD PAGE,  
HUBERT WILLOUGHBY CORBY.

## DISCLAIMER.

11,913. Reissue. *Guglielmo Marconi*, London, England. TRANSMITTING ELECTRICAL IMPULSES AND SIGNALS AND APPARATUS THEREFOR. Patent dated June 4, 1901.

Disclaimer filed March 10, 1906, by the assignee, Marconi Wireless Telegraph Co.

Enters its disclaimer—

"To said first claim."

"The first claim is as follows:

"1. In an apparatus for communicating electrical signals by means of a producer of Hertz oscillations, and a signaling instrument, the combination, in the receiver, of an imperfect electrical contact, a circuit through the contact, and a receiving instrument operated by the influence of such oscillations on said contact, substantially as and for the purpose described"—[*Official Gazette*, March 20, 1906.]

PLAINTIFF'S EXHIBIT 20

Lodge Patent in Suit (609154)

UNITED STATES

DEPARTMENT OF

UNITED STATES PATENT OFFICE.

To all to whom these presents shall come Greeting:

THIS IS TO CERTIFY that the annexed is a true copy from the Records

of this Office of the

Letters Patent of

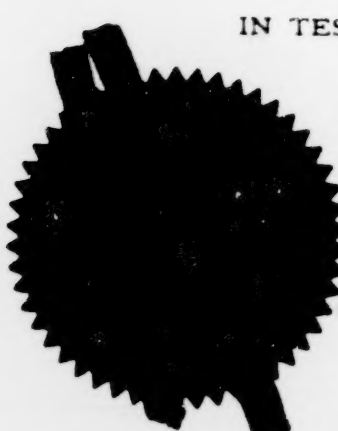
Oliver Joseph Lodge,

Number 609,154,

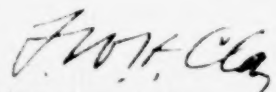
Granted August 15, 1898.

for

Improvement in Electrical Telegraphy.



IN TESTIMONY WHEREOF I have hereunto set my hand  
and caused the seal of the Patent Office to be affixed  
at the City of Washington, this 23rd day  
of September, in the year of our Lord one  
thousand nine hundred and sixteen and of  
the Independence of the United States of America the  
one hundred and forty-first.

  
Acting Commissioner of Patents.

No. 609,154

## THE UNITED STATES OF AMERICA,

TO ALL TO WHOM THESE PRESENTS SHALL COME:

Whereas

Oliver Joseph Lodge,

of

Liverpool, England,

has presented to the Commissioner of Patents a petition praying for the grant of Letters Patent for an alleged new and useful improvement in Electric Telegraphy,

a description of which invention is contained in the specification of which a copy is hereunto annexed and made a part hereof, and has complied with the various requirements of law in such case made and provided; and

Whereas upon due examination made the said claimant is adjudged to be justly entitled to a patent under the law;

Now therefore these Letters Patent are to grant unto the said

Oliver Joseph Lodge, his heirs or assigns for the term of seventeen years from the sixteenth day of August, one thousand eight hundred and ninety-eight, the exclusive right to make, use, and vend the said invention throughout the United States and the Territories thereof.

In testimony whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed, at the City of Washington, this sixteenth day of August, in the year of our Lord one thousand eight hundred and ninety-eight, and of the Independence of the United States of America the one hundred and twenty-third.

[Seal]

Webster Davis

COUNTERSIGNED:

Assistant Secretary of the Interior.

A. P. Greeley

Acting Commissioner of Patents.

No. 609,154.

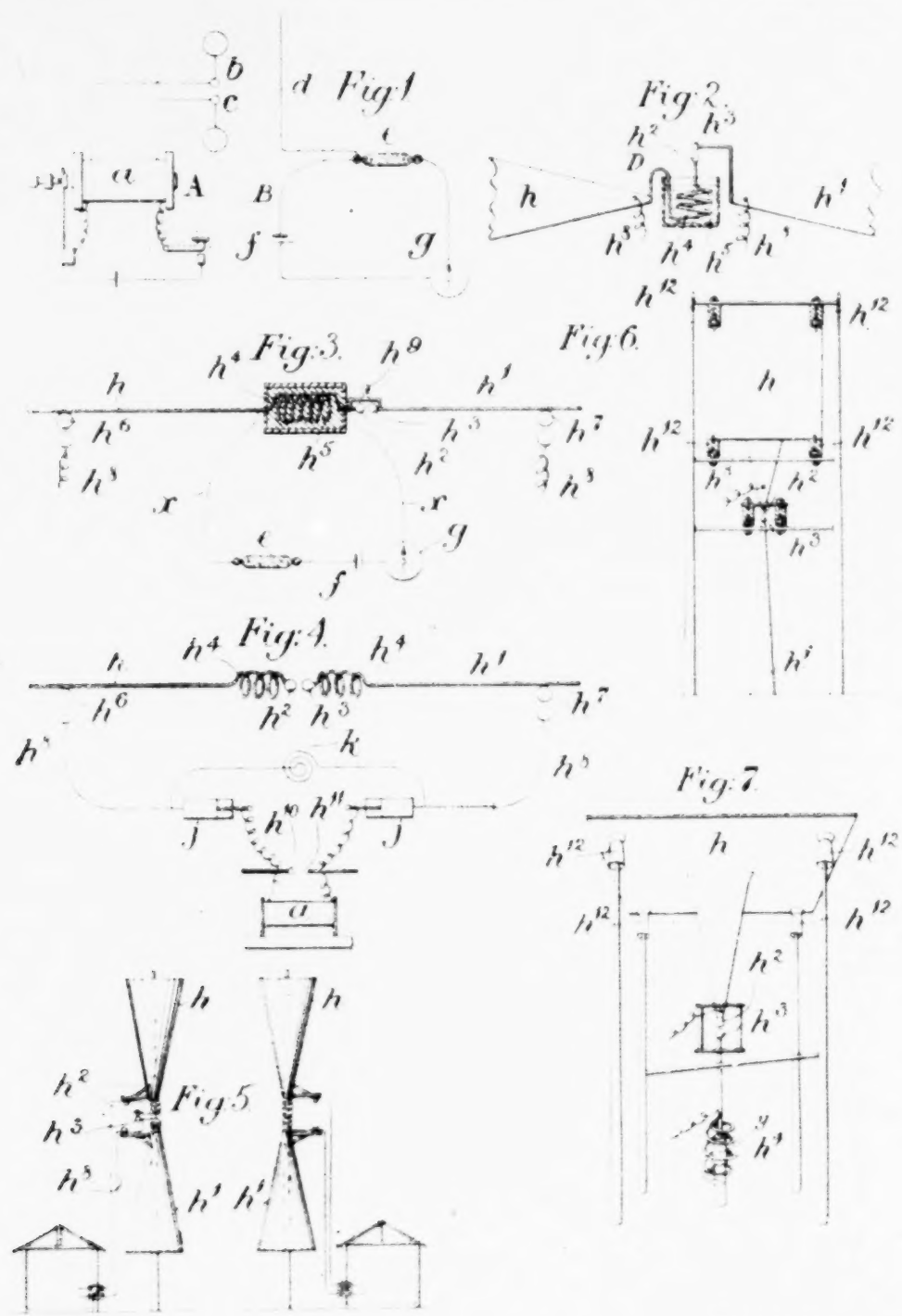
Patented Aug. 16, 1898.

O. J. LODGE.  
ELECTRIC TELEGRAPHY.

No Model

Application filed Feb. 1, 1898

2 Sheets—Sheet 1



Witnesses:  
*E. A. Bullock*  
*Manuel Thomas*

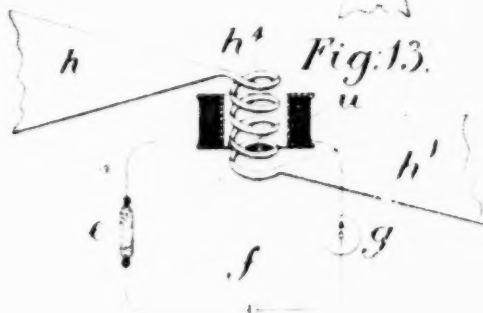
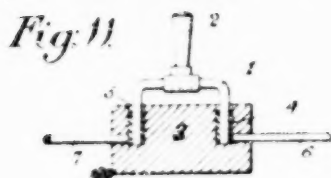
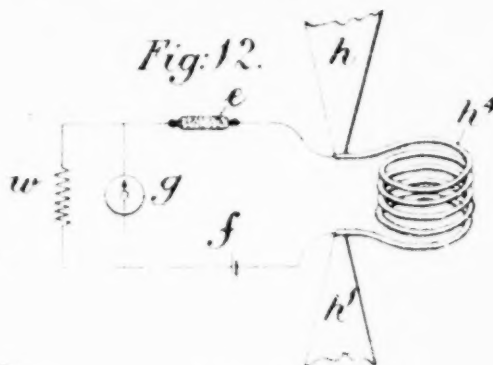
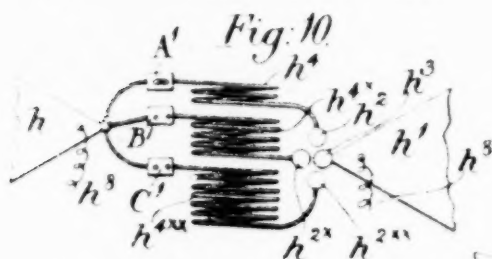
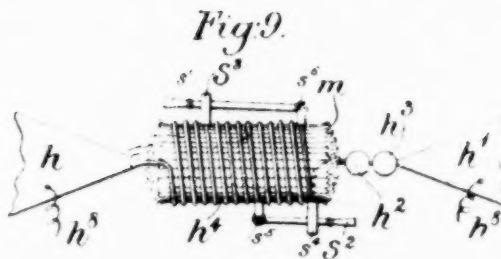
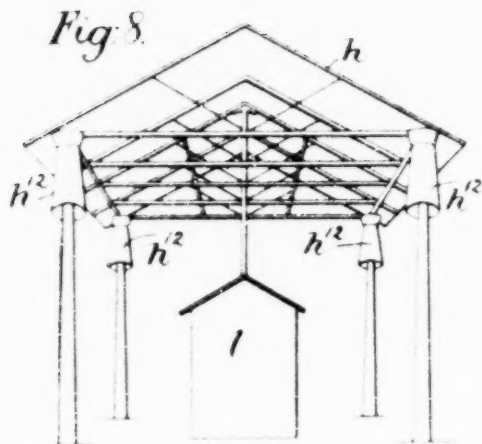
*Inventor*  
*Oscar Joseph Lodge*  
*By his Attorney*  
*William L. Landon*

O. J. LODGE.  
ELECTRIC TELEGRAPHY.

Application filed Feb. 1, 1898

(No Model.)

2 Sheets—Sheet 2.



Witnesses:

E. A. Bulloch

Manuel Thomas

Inventor:

Oleus Joseph Lodge

By his Attorney

Richard Lindon Wright

# UNITED STATES PATENT OFFICE.

2583

OLIVER JOSEPH LODGE, OF LIVERPOOL, ENGLAND.

## ELECTRIC TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 609,154, dated August 16, 1898.

Application filed February 1, 1898. Serial No. 668,752. No model.

*To all whom it may concern:*

Be it known that I, OLIVER JOSEPH LODGE, a subject of the Queen of Great Britain, residing at Liverpool, in the county of Lancaster, England, have invented certain new and useful Improvements in Electric Telegraphy, of which the following is a specification.

The object of my invention is to enable an operator, by means of what is now known as "Hertzian wave telegraphy," to transmit messages across space to any one or more of a number of different individuals in various localities, each of whom is provided with a suitably-arranged receiver, and to effect the ancillary improvements the nature of which are hereinafter more particularly described and claimed.

The method of intercommunication consists, according to my invention, in utilizing certain processes and apparatus for the purpose of producing and detecting a sufficiently-prolonged series of rapid electric oscillations and in so arranging them that the excitation of a particular frequency of oscillation at the sending station may cause a telegraphic instrument to respond at a distant station by reason of being associated, through a relay or otherwise, with a subsidiary circuit capable of electric oscillations of that same particular frequency or of some multiple or sub-multiple of that frequency. Another distant station will similarly be made to receive messages by exciting at the sending-stations alternations of a different frequency, and so on, and thus individual messages can be transmitted to individual stations without disturbing the receiving appliances at other stations which are tuned or timed or syntonized to a different frequency. Each station will usually be provided with both sending and receiving apparatus.

In the accompanying drawings, which are diagrammatic representations, Figure 1 shows the simplest arrangement of emitter and receiver heretofore in use. Figs. 2, 4, 6, 7, 8, 9, and 10 show alternative arrangements to be adopted at signaling-stations or appendages thereto in accordance with my invention. Fig. 3, in addition to showing an emitter, serves to show a receiving-circuit and means whereby parts of the emitting arrangement

is utilized for receiving purposes. Fig. 5 depicts the more prominent features of a long-distance arrangement, both sending and receiving. Figs. 12 and 13 illustrate alternative forms of connection of apparatus in a sytonic receiving-circuit with appendages, and Fig. 14 is a detail view hereinafter more particularly referred to.

Like letters and figures of reference indicate similar parts throughout the drawings.

A complete installation of Hertzian-wave telegraphy consists, in its simplest form, of the arrangement depicted in Fig. 1, wherein A represents the emitting apparatus, and B the receiving apparatus.

In the emitter illustrated in Fig. 1 electricity from a suitable source, such as a Ruhmkorff coil *a*, is supplied to a pair of conductors which discharge into each other from knobs *b* and *c* and thus excite oscillations, which emit one or two waves before they are damped out.

The receiving-circuit consists, essentially, of a collector *d*, a coherer *e*, a battery *f* or other suitable source of electrical energy, and a telegraphic receiving instrument *g*, all in electrical connection, as shown.

In carrying out my invention, and referring now to the subsequent figures of the drawings, I use a definite radiator consisting of a conductor or pair of conductors *h h'* of large capacity, arranged either as a Leyden jar or preferably spread out separately in space, one of them being the earth when desired. I join to *h* and *h'*, respectively, which I denominate "capacity areas," a pair of polished knobs *h'' h'''*, protected by glass from ultraviolet light, which form the adjustable spark-gap. Between either capacity area and its knob I place a syntonizing self-inductance coil—that is, a coil of wire or metallic ribbon *h''*, preferably insulated with any solid or fluid insulator, as in Fig. 2, or in air, of shape suitable to attain greatest inductance with a given amount of resistance—the object of this coil being to prolong the electric oscillations occurring in the radiator, so as to constitute it a radiator of definite frequency or pitch and obtain a succession of tone-waves emitted, and thereby to render sytony in a receiver possible, because exactitude of re-

sponse depends on the fact that the total number of oscillations in a suitably-arranged circuit is very great, so that a very feeble impulse is gradually strengthened by cumulative action until it causes a perceptible effect on the well-known principle of sympathetic resonance.

I supply the electricity to the radiator from a Ruhmkorff or from a Tesla coil or from a Wimshurst or other known or suitable high-tension machine *a* in one of three ways, according to circumstances.

The first way is by leading wires from the machine *a* to the two knobs  $h^2 h^3$ , which is the customary plan and gives a discharge which follows upon fairly steady electric strain.

The second way consists, as shown in Fig. 3, in having a supplementary pair of spark-gaps  $h^4 h^5$ , (which I call the "supply-gaps,") one knob of each (called the "receiving-knob") being attached to the middle or other convenient point of each capacity area  $h^1 h^2$ , and the other knob of each pair (called the "supply-knobs") being connected by wires  $h^3$  to the Ruhmkorff coil and brought moderately near the first, so that when the coil is in action the capacity areas shall receive their positive and negative charge by aerial disruption—that is, in a sudden manner—rather than by the slower process of metallic conduction, and shall then be left to discharge into each other through the connecting-coil  $h^4$  and across the short spark-gap between the knobs  $h^2 h^3$ . The best width of this gap depends upon circumstances, and it may be closed altogether without stopping the action. The gap between the knobs  $h^2 h^3$  may be optionally closed by a shunt  $h^2$ .

In the third plan, as indicated in Fig. 4, I interpose in each of the wires  $h^3$  leading from the Ruhmkorff coil *a* to the supply-knobs a Leyden jar or other suitable condenser capable to stand a high potential, so that the knobs are supplied from the outer—that is, the un-insulated—coat of each jar, while between the inner coats or coil-terminals I arrange a third spark-gap, (called the "starting-gap,") also consisting of suitable knobs  $h^4 h^5$ . The outer coats of the jars must not be insulated from each other, and I usually join them by an induction-coil of fairly thin wire  $h^6$ , so as to permit thorough charging. When the discharge occurs, this wire acts as an alternative path or by-pass, but does not prevent the sparks at the supply-gap.

By both of the means described with reference to Figs. 3 and 4 I charge the two capacity areas  $h^1 h^2$ , which, together with the induction-coil between them, constitute the radiator, by aerial disruption or impulsive rush. The advantage of this is that charges are immediately arrested, and are able free from any disturbance due to the induced current, with the addition of the induced current, and therefore are more effective in supplying than

when supplied by wires in the usual way. Moreover, the capacity areas of a radiator are more conveniently employed as the capacity areas of a receiver without need of disconnection.

The arrangement described with reference to Fig. 4 illustrates most completely the method of charging the capacity areas  $h^1 h^2$  with an impulsive rush. The action is as follows: The Ruhmkorff machine *a* charges the jars *j*, whose outer coats are connected, and discharges them at the starting-gap  $h^4 h^5$ . This spark precipitates a discharge at the supply-gaps  $h^2 h^3$  and suddenly supplies the capacity areas  $h^1 h^2$  with electric charges, which then surge through the connecting-coil  $h^4$  (divided into two parts in this figure) and spark into each other at the discharge-gap between the knobs  $h^2 h^3$ . This last discharge is the chief agent in starting the oscillations which are the cause of the emitted waves; but it is permissible in the arrangements of Figs. 3 and 4 to close this last gap when desired and so leave the oscillations to be started by the sparks at the supply-gaps only, whose knobs must in that case be polished and protected from ultra-violet light, so as to supply the electric charge in as sudden a manner as possible.

As charged surfaces or capacity areas spheres or square plates or any other metal surfaces may be employed; but I prefer, for the purpose of combining low resistance with great electrostatic capacity, cones or triangles or other such diverging surfaces with the vertices adjoining and their larger areas spreading out into space; or a single insulated surface may be used in conjunction with the earth, the earth or conductors embedded in the earth constituting the other oppositely-charged surface.

Radiation from an oscillator consisting of a pair of capacity areas is greater in the equatorial than in the axial direction, and accordingly when sending in all-directions is desired it is well to arrange the axis of the emitter vertical. Moreover, radiation polarized in a horizontal plane—that is, with its electric oscillations vertical—is less likely to be absorbed during its passage over partially-conducting earth or water. A pair of insulated capacity areas arranged for long-distance signaling is shown on the left-hand side of Fig. 5. Fig. 6 shows a single insulated capacity area *b* with the earth acting as the other surface and leading up to the spark knobs  $h^1 h^2$  by a triangular sheet or cone *c*, so as to afford good conductance even to rapidly alternating currents. The wire  $h^3$  in this case leads to one terminal of the Ruhmkorff coil, the other terminal of which is taken to earth. The capacity area *b* is insulated, as indicated at  $h^4$ .

It is now all that is required that the apparatus be so arranged that the waves in which the oscillations are sent out are such as that illustrated

in Fig. 7, where instead of being vertical, as shown in Fig. 6, the capacity area  $h$  is slanting or horizontal.

In Fig. 7 the synchronizing-coil  $h^1$  is shown as surrounding a large telegraph-insulator  $y$ , which insulator divides the upper from the lower part of the rod carrying the discharge-knob  $h^2$ . The spiral  $h^1$  bridges over the gap thus caused, uniting the rod above and below the insulator and so affording an earth connection.

Fig. 8 shows an insulated metal surface in the form of a roof of a shed or building which may be used as a capacity area, with suitable connection and apparatus (not shown) inside the little house  $l$ .

The self-inductance coil represented at  $h^1$  in all applicable figures is a coil of highly-conducting wire or ribbon, well insulated by air or by some other medium, as already described, or else covered to a sufficient thickness with insulating material of such shape as to have maximum self-inductance for a given resistance, and it may be either a flat coil inclosing a considerable plane area or it may be a cylindrical coil wound upon a finely-subdivided iron core, as shown at  $m$  in Fig. 9, the core being either ring-shaped or U-shaped or straight.

The discharge-knobs  $h^2$   $h^3$  may be arranged at one end of such coil, as shown in Figs. 2, 3, 7, and 9, or the coil may be in two halves with the knobs inserted in the middle, at pleasure. (See Figs. 4 and 5). Several such coils  $h^1$   $h^{1'}$   $h^{1''}$ , with their knobs  $h^2$ ,  $h^{2'}$ , and  $h^{2''}$ , may, as shown in Fig. 10, be arranged for use with a single pair of capacity areas, and any one of them may be brought into action by a suitable switch, so that the desired frequency of vibration or syntony at a particular distant station is attained by replacing one coil by another, for the frequency can be adjusted either by varying the capacity of the condenser or jar or other conductor employed or the charged body on the one hand or by varying the number and position of coils or other portion of the discharge-circuit on the other. That discharger is in action whose spark-gap is allowed to operate, and a switch A B C can determine which of a set of different coils shall be utilized for a given distant station. Fig. 11 illustrates the form of switch indicated in Fig. 10.

In Fig. 11 the numeral 1 designates a metallic union piece, 2 is its handle, of insulating material, and 3 is a suitable insulating base. The union-piece 1 dips into mercury cups 4 and 5, with which the leads 6 and 7 are connected.

A plan alternative to that described with reference to Fig. 10 is to connect the capacity areas through one pair of knobs and a single large coil of a considerable number of turns as shown in Fig. 9, and to have keys or plugs or switches  $s^1$  and  $s^2$ , whereby some of the spires or turns of the coil can be shunted out of ac-

tion, so that the whole or any smaller portion of the inductance available may be used in accordance with the correspondingly-attuned receiver at the particular station to which it is desired to signal.

Fig. 9 shows two hand-levers  $s^1$   $s^2$  hinged, respectively, to the coil at  $s^3$   $s^4$ . The bar of each lever is made of metal, while the handle is of insulating material.  $s^3$   $s^4$  are movable metallic spring-clips connected to the said coil and adapted to grip the levers when they are depressed, so as to make good contact. Thus each lever when pressed down shuts out all the spires of the coil between the two ends of such lever. This arrangement may be used either in lieu of or in combination with interchangeable inductance-coils, such as shown in Fig. 10, and in the latter case they are useful for correcting slight errors in tuning for any one station. The one I call an "adjustable" coil and the other I call "replaceable" or "interchangeable" coils, and both, since they tend to a like end and behave similarly, may be included by the term "variably-acting" coil.

A receiver or resonator consists of a similar pair of capacity areas connected by a similarly-shaped conductor or self-inductance coil, the whole constituting an absorber arranged so as to have precisely the same natural frequency of electrical vibration as the radiator in use at the corresponding emitting-station, so that it can accumulate the received impulses—that is to say, can act cumulatively; but it must not have a spark-gap, such as  $h^2$   $h^3$ , or if it have a spark-gap the same must be carefully closed or shunted or bridged across by a good short conductor—for example, like Fig. 11—before the arrangement can be properly used as a cumulative receiver. Identically the same capacity areas and self-inductance coil can be used at will either as emitter or as receiver—that is, either as radiator or as resonator (see Fig. 5)—if it be convenient to do so, on condition that the "discharge" spark-gap  $h^2$   $h^3$  of the radiator is perfectly closed whenever acting as receiver.

Thus referring to Fig. 3 it will be seen that that diagram illustrates a combined emitting and receiving apparatus. When in use as a radiator, the gap between the discharge-knobs  $h^2$   $h^3$  is left open. When utilized as a resonator, the said gap is closed by the shunt  $h^2$ , (there supposed to be like Fig. 11,) and the coherer  $c$ , battery  $f$ , and telegraphic receiving instrument  $g$  are connected through a thin wire  $x$  from each end of the coil  $h^1$ —that is, from each of the capacity areas.

If the Ruhmkorff machine  $a$  has been actually connected to the capacity areas  $h$   $h'$ , as in Fig. 2, then it must be detached and substituted by the coherer-circuit when a receiver is wanted; but if the charge was supplied through supply gaps  $h^2$   $h^3$ , as in Figs. 3 and 4, (and this is the best plan,) then the Ruhmkorff

kerff connections can be left unaltered, as the action of the resonator is then in no way affected, provided always that the coil is not put into activity while the receiving-circuit is connected up.

5 A coherer consists of any arrangement which drops in resistance on receipt of an electric impulse and rises to its old resistance on being subjected to a mechanical impulse, 10 such as a tremor or a tap.

A coherer-circuit is any known arrangement for observing or recording effects due to fluctuations in the electrical resistance of a coherer.

15 As coherer I use either a light single-point contact or Branly's arrangement of a pair of conductors embedded in metallic grains or powder or filings; but I prefer selected iron-filings of uniform size sealed up in a good vacuum and with the communicating sur- 20 faces or electrodes reduced to points or thin platinum wires fused into the glass and with their ends close together; or I may use any other suitable apparatus with an appropriate 25 device for tapping back. In some cases I find that a coherer restores itself sufficiently without specially-arranged tremor and that in these cases a telephone is the quickest res-ponder that can be used.

30 As coherer-circuit I usually arrange the coherer in simple series with a battery (voltaic or thermal) and a galvanometer, telephone, or other indicator, or a recorder of fluctu-ations of current, and I then connect the ter- 35 minals of this series of instruments to the capacity areas of the receiver close to its self-inductance coil, so that this same coil of wire completes and forms an essential part of the coherer-circuit. The coherer is thus affected by 40 every electrical disturbance occurring in the connecting-coil or in its capacity areas and by aid of the battery at once enables the tele-graphic or telephonic instrument to appreci-ate and indicate the signals. This plan is 45 shown in Figs. 3 and 12. It is an improve-ment on any mode of connection that has previously been possible without the connect-ing-coil.

In some cases I may, as shown in Fig. 13, 50 surround the syntonizing-coil of the resonator with another or secondary coil *u* (constituting a species of transformer) and make this lat-ter coil part of the coherer-circuit, so that it shall be secondarily affected by the alternat- 55 ing currents excited in the conductor of the resonator, and thus the coherer be stimulated by the current in this secondary coil rather than primarily by the currents in the synton-izing-coil itself, the idea being thus to leave 60 the resonator free to vibrate electrically with-out disturbance from attached wires.

In all cases it is permissible and sometimes desirable to shunt the coils of the telegraphic instrument by means of a resistance or a ca- 65 pacity, as shown at *w* in Fig. 12, in order to connect the coherer more effectively and

closely to the capacity areas or receiving ar-rangement whereby it is to be stimulated.

What I claim, and desire to secure by Let-ters Patent of the United States, is—

70 1. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, of a self-inductance coil inserted between them electrically for the purpose of prolong- 75 ing any electrical oscillations excited in the system and constituting such a system a ra-diator of definite frequency or pitch.

2. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, 80 of a self-inductance coil inserted between them electrically for the purpose of prolong-ing any electrical oscillations excited in the system, thus constituting the system a reso-nator or absorber of definite frequency or 85 pitch, and a distant radiator of corresponding period capable of acting cumulatively.

3. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, 90 of electrical means having a spark-gap in-serted between them and serving to syntonize them and means for bridging or shunting the spark-gap, whereby the apparatus is adaptable for use at will either as a radiator or resonator.

4. In a system of Hertzian-wave telegraphy, the combination, with a pair of capacity areas, 95 of a number of self-inductance coils having different amounts of self-induction each of which is capable of being switched in or out of circuit, serving to syntonize any such ra-diator to a corresponding resonator or vice 100 versa, whereby signaling may be effected be-tween any two or more correspondingly-at-tuned stations without disturbing other dif-ferently-tuned stations.

5. In a system of Hertzian-wave telegraphy, 105 the combination, with a pair of capacity areas, of a variably-acting self-inductance coil, serv-ing to syntonize such a radiator or resona-tor to any other such resonator or radiator, whereby signaling may be effected between 110 any two or more correspondingly-at-tuned sta-tions without disturbing other differently-at-tuned stations.

6. In combination, a pair of capacity areas connected by a coil of wire serving as the ra- 115 diator in a system of Hertzian-wave tele-graphy, means for syntonizing such radiator, and means for charging it by aerial disrup-tion or impulsive rush.

7. In a system of Hertzian-wave telegraphy, 120 the combination of a pair of capacity areas such as *h, h*, means for syntonizing such ca-pacity areas, a receiving-circuit completed through one or both of such capacity areas, and means for bridging over the discharge- 125 gap between such capacity areas when they are to be used as a receiver, whereby such capacity areas are rendered adaptable for use at will either as a radiator or resonator.

8. In combination, in a system of syntonie 130 Hertzian-wave telegraphy, a pair of capacity areas, a self-inductance coil and a secondary

coil surrounding said self-inductance coil, which secondary coil forms part of the coherer-circuit substantially as and for the purpose set forth.

- 5 9. The combination, in the receiving-circuit of a system of Hertzian-wave telegraphy, of a variably-acting self-inductance coil, connecting the capacity areas, a coherer, a battery, a receiving instrument, and a shunt

across the coils thereof substantially as and for the purpose set forth.

In testimony whereof I have hereunto subscribed my name.

OLIVER JOSEPH LODGE.

Witnesses:

A. F. SPOONER,

J. SUTTON.

2-39

UNITED STATES

DEPARTMENT OF

UNITED STATES PATENT OFFICE.

To all to whom these presents shall come, Greeting:

THIS IS TO CERTIFY that the annexed is a true copy from the Records

of this Office of the

Letters Patent of

Guglielmo Marconi, Assignor to

Marconi's Wireless Telegraph Company, Limited,

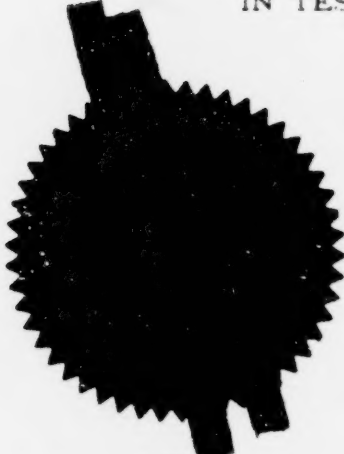
Number 763,772,

Granted June 28, 1904,

for

Improvement in Apparatus for Wireless Telegraphy.

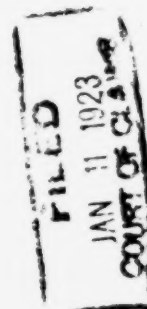
IN TESTIMONY WHEREOF I have hereunto set my hand  
and caused the seal of the Patent Office to be affixed  
at the City of Washington, this 23rd day  
of September, in the year of our Lord one  
thousand nine hundred and sixteen and of  
the Independence of the United States of America the  
one hundred and forty-first.

  
Acting Commissioner of Patents.

2228

2598

PLAINTIFF'S EXHIBIT # 21  
Marconi patent in suit (763,772)



No. 763,772,

## THE UNITED STATES OF AMERICA,

TO ALL TO WHOM THESE PRESENTS SHALL COME:

Whereas **Guglielmo Marconi,**  
of  
London, England,

has presented to the Commissioner of Patents a petition praying for the grant of Letters Patent for an alleged new and useful improvement in Apparatus for Wireless Telegraphy,

He having assigned his right, title, and interest in said improvement to Marconi's Wireless Telegraph Company, Limited, of London, England,

a description of which invention is contained in the specification of which a copy is hereto annexed and made a part hereof, and has complied with the various requirements of law in such case made and provided; and

Whereas upon due examination made the said claimant is adjudged to be justly entitled to a patent under the law;

Now therefore these Letters Patent are to grant unto the said

Marconi's Wireless Telegraph Company, Limited, their heirs or assigns for the term of seventeen years from the twenty-eighth day of June, one thousand nine hundred and four, the exclusive right to make, use, and vend the said invention throughout the United States and the Territories thereof.

In testimony whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed, at the City of Washington, this twenty-eighth day of June, in the year of our Lord one thousand nine hundred and four and of the Independence of the United States of America the one hundred and twenty-eighth.

[Seal]

E. B. Moore

Acting Commissioner of Patents.

G. MARCONI.  
APPARATUS FOR WIRELESS TELEGRAPHY.

APPLICATION FILED NOV 10, 1900

NO MODEL.

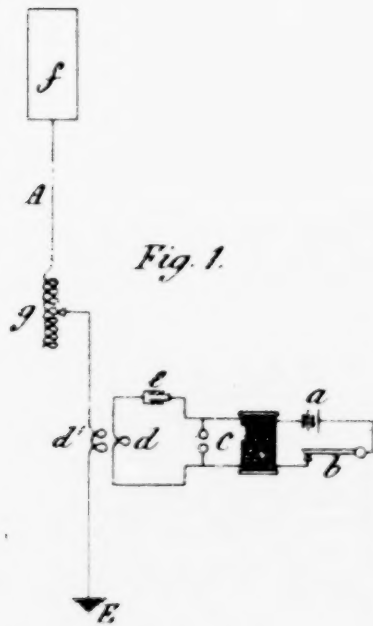


Fig. 1.

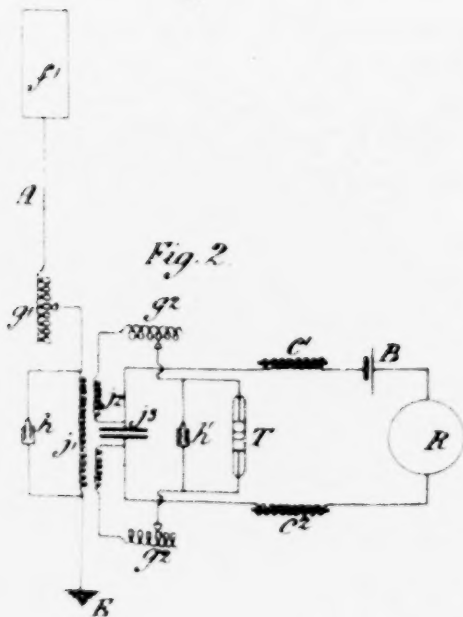


Fig. 2.

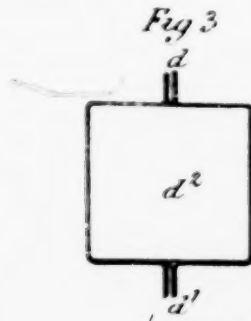


Fig. 3.



Fig. 4.

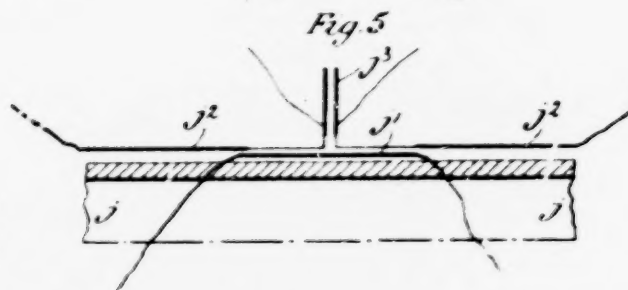


Fig. 5.



Fig. 6.

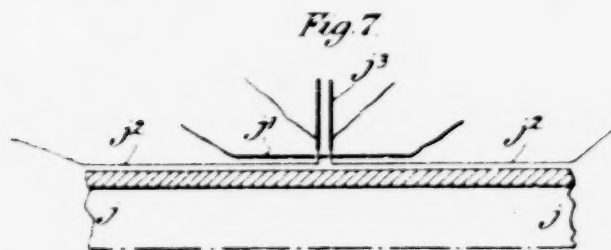


Fig. 7.

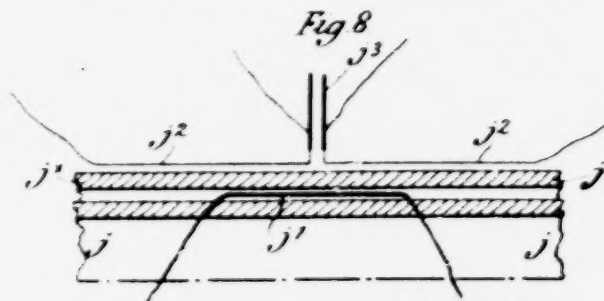


Fig. 8.

Witnesses  
*Amos B. ...*  
*...*

Inventor  
GUGLIELMO MARCONI,  
*...*

## UNITED STATES PATENT OFFICE.

GUGLIELMO MARCONI, OF LONDON, ENGLAND, ASSIGNOR TO MARCONI'S WIRELESS TELEGRAPH COMPANY, LIMITED, OF LONDON, ENGLAND.

## APPARATUS FOR WIRELESS TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 763,772, dated June 28, 1904.

Application filed November 10, 1900. Serial No. 36,010. No model.

*To all whom it may concern:*

Be it known that I, GUGLIELMO MARCONI, electrician, a subject of the King of Italy, residing and having a post-office address at 18 Finch Lane, Threadneedle street, in the city of London, England, have invented certain new and useful Improvements in Apparatus for Wireless Telegraphy, of which the following is a specification.

My invention relates to apparatus for communicating electrical signals without wires and by means of Hertz oscillations or electric waves; and the object of the invention is to increase the efficiency of the system and to provide new and simple means whereby oscillations or electric waves from a transmitting-station may be localized when desired at any one selected receiving station or stations out of a group of several receiving-stations.

In my prior United States patent No. 586,493 (Reissue No. 11,913, dated June 4, 1901) I have shown and described the combination at a transmitting-station of an oscillation-producer, such as an induction-coil, having one end of its secondary coil connected to one contact of a spark-producer and to the earth and having the other end of the said secondary connected to the opposite contact of the spark-producer and to a vertical wire or elevated plate, and I have further shown at a receiving-station an imperfect contact connected in circuit with a vertical receiving-wire and with the earth. According to the present invention the system includes at the transmitting-station the combination, with an oscillation-transformer of a kind suitable for the transformation of very rapidly alternating currents, of a persistent oscillator, and a good radiator, one coil of said transformer being connected between the aerial wire or plate and the connection thereof to earth, while the other coil of the transformer is connected in circuit with a condenser, a producer of Hertzian oscillations or electric waves shown in the form of a spark-producer, and an induction-coil (constituting the persistent oscillator) controlled by a signaling instrument. The complete system also includes at a receiving-station an oscillation-transformer one coil whereof is

included between the aerial receiving-wire and earth, constituting a good absorber of electrical oscillations, while a device responsive to electric waves, such as an imperfect contact or a device for operating the same, is included in a circuit with the other coil of said transformer. The system also requires as essential elements thereof the inclusion in the lines (at both stations) from the aerial conductor to the earth of variable inductances and the use at both stations of means for varying or adjusting the inductance of the two circuits at each station to accord with each other. By this arrangement of apparatus I am able to secure a perfect "tuning" of the apparatus at a transmitting-station and at one or more of a number of receiving-stations.

Referring to the accompanying drawings, Figure 1 indicates diagrammatically the arrangement of apparatus at a transmitting-station. Fig. 2 indicates diagrammatically an arrangement of apparatus at a receiving-station. Figs. 3 and 4 are views, plan and side, of the preferred form of transformer at the transmitting-station. Figs. 5, 6, 7, and 8 are diagrammatic views of forms of transformers at the receiving-station.

The transmitting-station is provided under my present invention with a source *b* of current electrically connected in circuit with the primary of an induction-coil *c* and with a circuit-closing key *d* or otherwise controlled by a signaling instrument. In the secondary circuit of said induction-coil the spherical terminals or other contacts of a spark-producer or other electric-wave or oscillation producer are included with a shunt therefrom, in which shunt is included the primary coil *e* of an oscillation-transformer, such as *f*. A condenser *g*, preferably one provided with two telescoping metallic tubes separated by a dielectric and arranged to readily vary the capacity by being slid upon each other, is included in one connection from the induction-coil to the transformer winding *e*. The secondary coil *h* of the transformer is connected (at one end) to the earth *E* and at its other end to a vertical wire *A* or an elevated plate *z*.

It is obvious that instead of the induction-

coil and associated parts for producing the electric waves or oscillations I may use any other proper means for producing such waves or oscillations—such, for instance, as a generator of alternating electric currents.

The illustrated arrangement of parts at a transmitting station enables much more energy to be imparted to the radiator  $f$ , the approximately closed circuit of the primary being a good conserver and the open circuit of the secondary being a good radiator of wave energy. My experiments have demonstrated that the best results are obtained at the transmitting station when I use a persistent oscillator—an electrical circuit of such a character that if electromotive force is suddenly applied to it and the current then cut off electrical oscillations are set up in the circuit which persist or are maintained for a long time in the primary circuit and use a good radiator  $f$ , i. e., an electrical circuit which very quickly imparts the energy of electrical oscillations to the surrounding ether in the form of waves in the secondary circuit.

In operation the signaling-key  $b$  is pressed, and this closes the primary of the induction-coil. Current then rushes through the transformer-circuit and the condenser  $c$  is charged and subsequently discharges through the spark-gap. If the capacity, the inductance, and the resistance of the circuit are of suitable values, the discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer and induce similar oscillations in the secondary, these oscillations being rapidly radiated in the form of electric waves by the elevated conductor.

For the best results and in order to effect the selection of the station or stations whereat the transmitted oscillations are to be localized I include in the open secondary circuit of the transformer, and preferably between the radiator  $f$  and the secondary coil  $d$ , an inductance-coil  $g$ , Fig. 1, having numerous coils, and the connection is such that a greater or less number of turns of the coil can be put in use, the proper number being ascertained by experiment.

At the receiving stations employing my present invention I prefer to use a receiver such as those described in my several United States Patents, Nos. 586,193, 627,659, 647,907, 647,608, 647,009, and 668,315, capable of being affected by electrical waves or oscillations of high frequency.

As a responder to electric waves I may use at the receiving station any of the now well-known forms of such devices, such as those which depend for their action on the reduction of the resistance of a metallic microphone by the action of electric waves or "coherers," or any form of device as disclosed in my Patent No. 668,315, or I may employ one which depends for its action on the increase of the re-

sistance of the device under the influence of the electric waves or "anticoherers," such as described by Branly in *La Lumière Electrique* of June 13, 1891, or I may use those which depend upon the action of an electric wave as a magnetizing or demagnetizing agency, such as I have disclosed in my application Serial No. 132,974, filed November 28, 1902, or I may use various other well-known devices, such as the electrolytic, electrothermal, electromagnetic, or electrodynamic responders.

Referring to Fig. 2,  $f''$  indicates a plate or cylinder (not essential at either transmitter or receiver) at the upper end of an elevated conductor  $A$ , which is connected to the primary coil  $j'$  of a transformer or induction-coil and thence to earth  $E$ . In a shunt around said primary  $j'$  I usually place a condenser  $h$ , preferably similar in construction and operation to the condenser  $c$ . An inductance-coil  $g'$  of variable inductance is interposed in the primary circuit of the transformer, being preferably located between the cylinder  $f''$  and the coil  $j'$ , and the inductance of said coil may be adjusted in accordance with the method described by me in my Letters Patent of the United States No. 676,332 to harmonize with the inductance of coil  $g$  at the transmitting station, Fig. 1 of the accompanying drawings, or with that of the coil or coils at one or more of the transmitting stations included in the communicating system.

The secondary coil  $j''$  of the transformer is wound in two parts, preferably as described in my United States Letters Patent No. 668,315, dated February 19, 1901, and the outer ends of said coil are connected in certain cases through one or more interposed inductance-coils  $g''$ , preferably of variable inductance, with the terminals of a coherer  $T$  or other detector of electrical oscillations. The inner ends of the split secondary coil are connected to the plates of a condenser  $j''$ . A condenser  $h'$  is sometimes included in a shunt around the detector  $T$ .  $B$  is a battery, and  $R$  a relay connected to the condenser  $j''$  and controlling a telegraphing instrument or a printing device.  $c'$  and  $d'$  are choking-coils preventing oscillations from the secondary  $j''$  running into the battery-circuit, and thereby confining them to the wave-responsive device.

The capacity and self-induction of the four circuits  $L, c$ , the primary and secondary circuits at the transmitting station and the primary and secondary circuits at any one of the receiving stations in a communicating system, are each and all to be so independently adjusted as to make the product of the self-induction multiplied by the capacity the same in each case or multiples of each other; that is to say, the electrical time periods of the four circuits are to be the same or multiples of each other.

In employing this invention to localize the

transmission of intelligence at one of several receiving-stations the time period of the circuits at each of the receiving-stations is so arranged as to be different from those of the other stations. If the time periods of the circuits of the transmitting-station are varied until they are in resonance with those of one of the receiving-stations, that one alone of all of the receiving-stations will respond, provided that the distance between the transmitting and receiving stations is not too small.

The adjustment of the self-induction and capacity of any or all of the four circuits can be made in any convenient manner and employing various arrangements of apparatus, those shown and described herein being preferred. In practice I have found the following preferred details of arrangements of apparatus to work well: The aerial conductors A at all stations and the conductor for the transformer windings at the receiving-stations are composed of seven strands of copper wire .889 millimeters in diameter. The transformer at the transmitting-station may be of any of the following forms:

1. Around a block or core  $d'$ , preferably a square block say .17 meters wide of insulating material is wound a primary coil  $d$  in length .946 meters, while the secondary  $d''$  consists of two turns or squares, one lying on each side of the primary. (See Figs. 3 and 4.) The insulation of both primary and secondary consists of 1.25 millimeters of rubber and one millimeter of jute, making a total thickness of 2.25 millimeters.

2. A transformer in all essential respects similar to 1, but with a primary of 1.93 meters and the core or block on which both primary and secondary are wound, is .3048 meters wide.

3. A transformer having a cylindrical core 10.16 centimeters in diameter and with a primary having ten turns wound thereon; over this, but separated by two millimeters of paper or other insulant, the secondary, also of ten turns.

Various forms of transformers, &c., which may be employed by me are described in my British Patent No. 7,777 of 1900.

The inductance-coils  $g$  and  $g'$  are preferably of copper wire 6.25 millimeters in diameter, wound on a cylinder 10.64 centimeters in diameter, with an interval of 2.28 millimeters between adjacent turns. The inductance-coils  $g''$  at the receiving-station are preferably of silk-covered copper wire .19 millimeter diameter wound upon cylinders 3.7 centimeters in diameter.

Various forms of induction-coils  $j$ ,  $j''$  may be used. Figs. 5, 6, 7, and 8 show details of different forms. The figures show diagrammatically greatly-enlarged longitudinal sections not strictly to scale. Instead of showing the section of each coil or layer of wire as a longitudinal row of dots or small circles,

as it would actually appear, it is for simplicity shown as a continuous longitudinal straight line.

Referring to Fig. 5, the primary  $j'$  preferably consists of 3.046 meters of silk-covered copper wire, say, and seventy-one millimeters in diameter wound in one layer on a core of ebonite or other insulating material 2.9 centimeters in diameter. Insulating material is wound over and on each side of this, so as to make a cylindrical core, say, 3.13 centimeters in diameter, on which is wound the secondary, each half of which consists of 6.4 meters of silk-covered copper wire .19 millimeter in diameter joined to 13.41 meters of silk-covered copper wire .37 millimeter in diameter wound in the same sense as the primary, the thinner wire being over the primary and the thicker being beyond the ends thereof.

The form of induction-coil shown in Fig. 6 has a primary of one hundred turns of copper wire .027 centimeters in diameter wound on a core  $j$  (2.9 centimeters in diameter) with a single silk covering and coated with paraffin-wax. The secondary  $j''$  is of copper wire .019 in diameter, insulated with a single silk covering, and is wound over the primary, commencing in the middle and in the same way as the primary. Each half of the secondary is in layers of the following number of turns: first layer, seventy-seven turns; second layer, forty-nine turns; third layer, forty-six turns; fourth layer, forty-three turns; fifth layer, forty turns; sixth layer, thirty-seven turns; seventh layer, thirty-four turns; eighth layer, thirty-one turns; ninth layer, twenty-eight turns; tenth layer, twenty-five turns; eleventh layer, twenty-two turns; twelfth layer, nineteen turns; thirteenth layer, sixteen turns; fourteenth layer, thirteen turns; fifteenth layer, ten turns; sixteenth layer, seven turns; and seventeenth layer, three turns, making five-hundred turns in all.

A third form of induction-coil (shown in Fig. 7) has a primary of 3.048 meters of silk-covered copper wire .19 millimeter in diameter and a secondary of 30.48 meters of silk-covered copper wire .1 millimeter in diameter wound in one layer on a core four centimeters in diameter, the primary being in one layer outside of the secondary.

The fourth form of induction-coil is shown in Fig. 8. Its primary consists of 3.048 meters of silk-covered copper wire .27 millimeter in diameter wound on a core 2.9 centimeters in diameter and inserted in a tube  $j''$  of four centimeters external diameter, on which is wound the secondary of 27.432 meters of silk-covered copper wire .12 millimeter in diameter, the break at the middle of the secondary being over the middle of the primary.

Other forms of transformers which may be employed by me are described and claimed in my British Patent No. 7,777 of 1900.

The following tables give preferred adjustments, those details opposite any tune in the transmitting-station table being of course used in connection with those opposite the same tune in the receiving-station table:

Transmitting-Station.

Tune	Aerial conductor	Transformer <i>d d'</i>	Inductance number of turns <i>d g</i> in circuit	Capacity microfarads <i>c</i>	Length of spark in millimeters
No. 1	36.576 meters of cable	No. 1	None.	.005234	3
No. 2	do	No. 1	45	.016296	4
No. 3	do	No. 2	None.	.004112	3
No. 4	do	No. 2	100	.016249	4
No. 5	Zinc cylinder 9.144 meters long, 1.524 meters in diameter, and hoisted 3.048 meters above ground.	No. 3	None	.005600	12.5
No. 6	30.48 meters of cable	No. 3	None.	.00573	4

Receiving-Station.

Tune	Induction coil	Capacity in microfarads of—		Inductance introduced in—	
		<i>A</i>	<i>A'</i>	Number of turns <i>g'</i>	<i>g''</i>
No. 1	No. 1	Omitted.	Omitted.	None	None
No. 2	No. 1	Omitted.	.0004	45	None
No. 3	No. 2	.0046	Omitted.	Up to 21 may be inserted.	None.
No. 4	No. 2	.0046	Omitted.	100	2 coils of 15.24 meters at each end of secondary
No. 5	No. 3	Omitted.	Omitted.	None	None
No. 6	No. 4	Omitted.	Omitted.	None	None

It will be observed that both the transmitter and the receiver are the same for tunes 1 and 2 and that when the capacity of the condenser *c* is varied the two stations can be brought into tune by including forty five turns of each of the coils *g g'* and by introducing a condenser *h'* of small capacity in parallel with the coherer T. Similarly the transmitter and receiver are the same for tunes 3 and 4, and when the capacity of *c* is varied the stations are tuned by including one hundred turns of each of the coils *g* and *g'* and by also including the coils *g''*.

While I have herein shown and described details of construction and of arrangement found by me to be useful, yet I do not wish to be understood as confining my claims thereto. Obviously modifications which are within my invention will readily suggest themselves to skilled persons.

What I claim is

1. At a station employed in a wireless-tele-

graph system, a signaling instrument comprising an induction-coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency; an open circuit electrically connected with the oscillation-producer aforesaid and a variable inductance included in the open circuit, substantially as and for the purpose described.

2. At a station employed in a wireless-telegraph system, an oscillation-receiving conductor, a variable inductance connected with said conductor; a wave-responsive device electrically connected with said conductor and in circuit with a condenser, substantially as and for the purpose described.

3. At a station employed in a wireless-telegraph system, a signaling instrument comprising an induction-coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency, and the

primary circuit of which includes a generator; means for varying the primary circuit; an open circuit electrically connected with the oscillation-producer aforesaid, and a variable inductance included in the open circuit, substantially as and for the purpose described.

4. In a system of syntonic wireless telegraphy, a circuit so arranged as to form a persistent oscillator, a circuit so formed as to constitute a good radiator in inductive relation thereto, means for inducing in the oscillator-circuit electric undulations of a predetermined period, and means for attuning the natural period of vibration of each of said circuits to the period of the undulations so induced.

5. An element of an apparatus employed in a system of telegraphy by electric waves or oscillations of high frequency, comprising a conductor elevated at one end and connected to capacity at the other end, said conductor including a variable inductance and an element having appreciable capacity.

6. At a transmitting-station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating-conductor at one end and capacity at the other end, and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, and means for adjusting the oscillation period of each of the two circuits connected with the transformer to bring them into accord with each other, substantially as described.

7. An element of an apparatus employed in a system of telegraphy by electric waves or oscillations of high frequency, comprising an open circuit so arranged as to constitute a radiator of such waves or oscillations, and means for varying at will the natural period of vibration of the said circuit.

8. At a transmitting-station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating-conductor at one end and capacity at the other end, a variable inductance being included in said circuit, and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, substantially as described.

9. At a transmitting-station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating-conductor at one end and capacity at the other end, a variable inductance being included in said circuit, and whose primary is connected in series with an adjustable condenser and with a means which automatically causes oscillations of the desired frequency, substantially as described.

10. A system of wireless telegraphy, in which the transmitting-station and the receiving-station each contains an oscillation-transformer, one circuit of which is an open circuit and the other a closed circuit, the two circuits at each station being in electrical resonance with each other and in electrical resonance with the circuits at the other station, substantially as described.

11. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an induction-coil; an electric circuit containing the secondary of said coil, a condenser and the primary coil of the oscillation-transformer; a producer of electric waves of high frequency electrically connected with the secondary of the induction-coil; a signaling instrument in circuit with the primary of the induction-coil; the secondary coil of the oscillation-transformer electrically connected, at one end to capacity and, at the other end, to an inductance, and an aerial conductor connected to the inductance, substantially as and for the purpose described.

12. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an induction-coil; an electric circuit containing the secondary of the said coil a condenser and the primary coil of the oscillation-transformer; a producer of electric waves of high frequency connected with the secondary of the induction-coil; a signaling instrument in circuit with the primary of the induction-coil; the secondary coil of the oscillation-transformer electrically connected, at one end, to capacity and, at the other end, to a variable inductance, and an aerial conductor connected to the variable inductance, substantially as and for the purpose described.

13. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a variable inductance being included in said circuit, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and a condenser in circuit with the wave-responsive device, substantially as described.

14. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described.

15. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a condenser located in said circuit between the coil and the capacity, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described.

16. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, an adjustable condenser in a shunt connected with the open circuit and around said transformer-coil, a wave-responsive device electrically connected with the other coil of the oscillation-transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described.

17. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and means included in each of said transformer-circuits, for adjusting said circuits in electrical resonance with each other, substantially as described.

18. At a receiving-station employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving con-

ductor at one end, and capacity at the other end, a variable inductance being included in said open circuit, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and a variable inductance included in circuit with the wave-responsive device, substantially as described.

19. In a system of wireless telegraphy, the combination at a receiving-station, of an oscillation-transformer; an open circuit comprising, in part, an aerial conductor connected with one end of the primary coil of the oscillation-transformer; a connection from the other end of said coil to capacity; a variable inductance in said open circuit; and electrical connections from the secondary coil of the oscillation-transformer to a receiving instrument, battery, condenser, wave-responsive device and a variable inductance, substantially as and for the purpose described.

20. In a system of wireless telegraphy, a transmitting-station containing an oscillation-transformer, the primary of which is connected to a condenser-circuit discharging through a spark-gap which automatically causes electric waves of the desired frequency, the secondary of said transformer connected to an open circuit including a radiating-conductor, and with a capacity and a coil for charging the condenser aforesaid; a receiving-station containing an oscillation-transformer, the primary of which is connected with an oscillation-receiving conductor and with a capacity, a wave-responsive device connected with the secondary of said transformer, and a receiving instrument connected with the wave-responsive device, all in combination with means for bringing the four transformer-circuits, two at each station, into electrical resonance with each other, substantially as described.

GUGLIELMO MARCONI.

Witnesses:

R. B. RANSFORD,

G. F. WARREN.

2-3

UNITED STATES

DEPARTMENT OF

UNITED STATES PATENT OFFICE.

To all to whom these presents shall come, Greeting:

THIS IS TO CERTIFY that the annexed is a true copy from the Records

of this Office of the

Letters Patent of

John Ambrose Fleming, Assignor to

Marconi Wireless Telegraph Company of America,

Number 803,684,

Granted November 7, 1905,

for

Improvement in Instruments for Converting Alternating Electric Currents into

Continuous Currents.

IN TESTIMONY WHEREOF I have hereunto set my hand

and caused the seal of the Patent Office to be affixed  
at the City of Washington, this 27th day  
of September, in the year of our Lord one  
thousand nine hundred and sixteen and of  
the Independence of the United States of America the  
one hundred and forty-first.

*Thomas A. Edison*  
Commissioner of Patents.

No. 803,584.

## THE UNITED STATES OF AMERICA,

TO ALL TO WHOM THESE PRESENTS SHALL COME:

Whereas John Ambrose Fleming,

of

London, England,

has presented to the Commissioner of Patents a petition praying for the grant of Letters Patent for an alleged new and useful improvement in Instruments for Converting Alternating Electric Currents into Continuous Currents,

He having assigned his right, title, and interest, in said improvement, to Marconi Wireless Telegraph Company of America, a corporation of New Jersey,

a description of which invention is contained in the specification of which a copy is hereto annexed and made a part hereof, and has complied with the various requirements of law in such case made and provided; and

Whereas upon due examination made the said claimant is adjudged to be justly entitled to a patent under the law;

Now therefore these Letters Patent are to grant unto the said Marconi Wireless Telegraph Company of America, its successors

~~heirs~~ or assigns for the term of seventeen years from the seventh day of November, one thousand nine hundred and five, the exclusive right to make, use, and vend the said invention throughout the United States and the Territories thereof.

In testimony whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed, at the City of Washington, this seventh day of November, in the year of our Lord one thousand nine hundred and five, and of the Independence of the United States of America the one hundred and thirtieth.

[Seal]

F. I. Allen

Commissioner of Patents.

No. 803,684.

PATENTED NOV. 7, 1905.

J. A. FLEMING.

INSTRUMENT FOR CONVERTING ALTERNATING ELECTRIC CURRENTS  
INTO CONTINUOUS CURRENTS.

APPLICATION FILED APR 19, 1905.

Fig 1

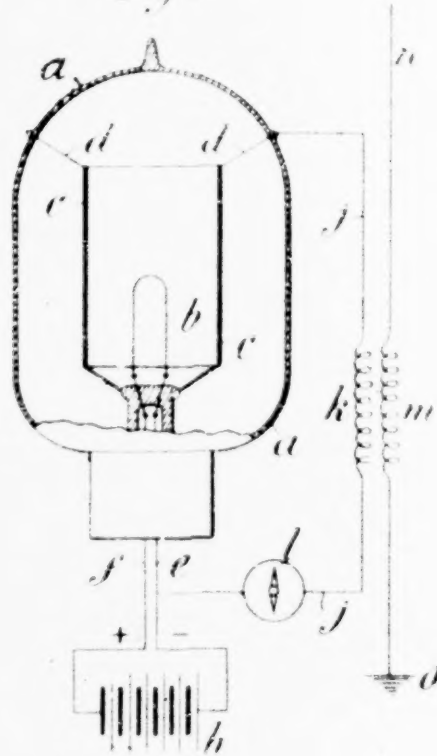


Fig 2

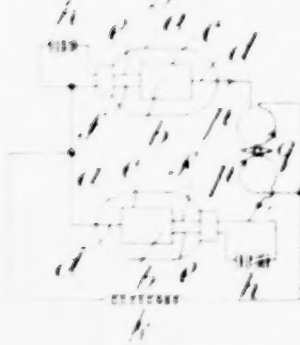
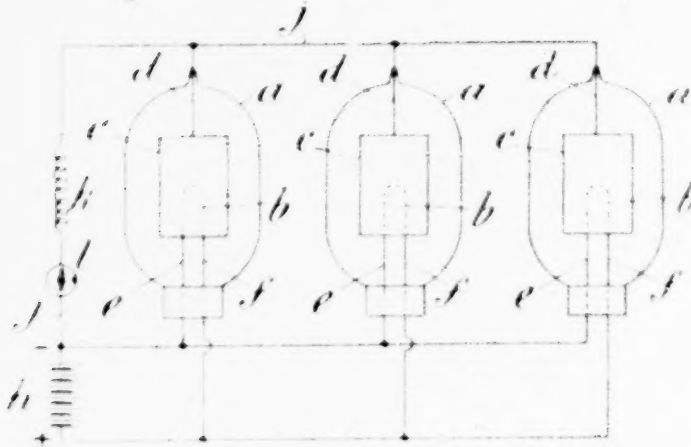


Fig 3



Witnesses

William H. Davis  
James J. Osborn

Inventor

John Ambrose Fleming  
by his atty. in law  
R. B. B. Hubbard & Co.

# UNITED STATES PATENT OFFICE. 2600

JOHN AMBROSE FLEMING, OF LONDON, ENGLAND, ASSIGNOR TO MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA, A CORPORATION OF NEW JERSEY.

INSTRUMENT FOR CONVERTING ALTERNATING ELECTRIC CURRENTS INTO CONTINUOUS CURRENTS.

No. 803,684.

Specification of Letters Patent.

Patented Nov. 7, 1905.

Application filed April 19, 1905. Serial No. 256,483.

*To all whom it may concern:*

Be it known that I, JOHN AMBROSE FLEMING, professor of electrical engineering, a subject of the King of Great Britain, residing at University College, Gower street, London, in the county of Middlesex, England, have invented certain new and useful Improvements in Instruments for Converting Alternating Electric Currents into Continuous Currents, of which the following is a specification.

This invention relates to certain new and useful devices for converting alternating electric currents, and especially high-frequency alternating electric currents or electric oscillations, into continuous electric currents, for the purpose of making them detectable by and measurable with ordinary direct-current instruments, such as a "mirror-galvanometer" of the usual type or any ordinary direct-current ammeter. Such instruments as the latter are not affected by alternating electric currents either of high or low frequency, which can only be measured and detected by instruments called "alternating-current" instruments of special design. It is, however, of great practical importance to be able to detect feeble electric oscillations, such as are employed in Hertzian-wave telegraphy by an ordinary movable coil or movable needle mirror-galvanometer. This can be done if the alternating current can be "rectified," that is, either suppressing all the constituent electric currents in one direction and preserving the others or else by changing the direction of one of the sets of currents which compose the alternating current so that the whole movement of electricity is in one direction. Many means have been devised and are in use for rectifying low-frequency alternating currents, such as are used in electric lighting. There are well-known forms of mechanical rectifier, also, there is a well-known form of electrochemical rectifier, depending on the fact that when a plate of carbon and aluminium is placed in any electrolyte which yields oxygen on electrolysis an electric current can only pass through this cell in one direction if below a certain voltage. Both these forms of rectifier are, however, inapplicable for high-frequency currents. I have found that the aluminium-carbon cell will not act with high-frequency currents.

I have discovered that if two conductors

are inclosed in a vessel in which a good vacuum is made, one being heated to a high temperature, the space between the hot and cold conductors possesses a unilateral electric conductivity, and negative electricity can pass from the hot conductor to the cold conductor, but not in the reversed direction. As the hot conductor should be heated to a very high temperature—say near to the melting-point of platinum, (1,700° centigrade) it should be of carbon, preferably in the form of a filament such as is used in any ordinary incandescent electric lamp. The cold conductor may be of many materials; but I prefer a bright metal, such as platinum or aluminium or else carbon. The two conductors are inclosed in a glass bulb similar to that of an incandescent lamp, and I generally heat the carbon filament to a high state of incandescence by a continuous electric current, the electrical connection to the filament and the cold conductor being made by platinum wires, sealed air-tight through the glass.

Figure 1 is a full-size sectional elevation of an instrument constructed according to this invention, the electrical connections being shown diagrammatically. This figure illustrates the application of the invention to wireless telegraphy. Figs. 2 and 3 show modifications to smaller scales.

In Fig. 1, *a* is a glass bulb, and *b* is a carbon filament like the carbon filament of an incandescent lamp, suitable, say, for taking a current of six to eight volts and two to four amperes. *c* is a cylinder of aluminium, open at the top and bottom, which surrounds but does not touch the filament. The cylinder *c* is suspended and steadied by platinum wires *d*, and the ends of the filament *b* are connected to platinum wires connected to the leads *e* and *f*. The platinum wires are sealed through the glass in the ordinary manner.

As a very high vacuum should be obtained in the bulb *a* and as a considerable quantity of air is occluded in the conductors, these should be heated when the bulb is being exhausted. The filament *b* can be conveniently heated by passing a current through it, while the cylinder *c* can be heated by surrounding the bulb *a* with a resistance-coil through which a current is passed, the whole being inclosed in a box lined with asbestos or the like. When, as hereinafter described, the cylinder *c* is re-

10. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for heating the filament, and a circuit outside the vessel connecting the filament to the cylinder.

11. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for passing an electric current through the filament, and a circuit outside the vessel connecting the filament to the cylinder.

12. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for heating the filament, a circuit outside the vessel connecting the filament to the cylinder, means tending to produce an alternating current in the circuit, and means for detecting a continuous current in it.

13. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for passing an electric current through the filament, a circuit outside the vessel connecting the filament to the cylinder, means tending to produce an alternating current in the circuit, and means for detecting a continuous current in it.

14. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for passing a continuous electric current through the filament, and a circuit outside the vessel connecting the filament to the cylinder.

15. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for passing a continuous electric current through the filament, a circuit outside the vessel connecting the filament to the cylinder, means tending to produce an alternating current in the circuit, and means for detecting a continuous current in it.

16. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for heating the filament, a circuit outside the vessel connecting the filament to the cylinder, an induction-coil having its secondary winding in the circuit and its primary winding connected to an aërial wire and earth, and means for detecting a continuous current in the circuit.

17. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for passing an electric current through the filament, a circuit outside the vessel connecting the filament to the cylinder, an induction-coil having its secondary winding in the circuit and its primary winding connected to an aerial wire and earth, and means for detecting a continuous current in the circuit.

18. The combination of a vacuum vessel, a carbon filament in the vessel, a metallic cylinder surrounding but not touching the filament, means for passing a continuous electric current through the filament, a circuit outside the vessel connecting the filament to the cylinder, an induction-coil having its secondary winding in the circuit and its primary winding connected to an aerial wire and earth, and means for detecting a continuous current in the circuit.

19. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for heating one of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, and a circuit connecting the two latter connections.

20. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for passing an electric current through and so heating one of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, and a circuit connecting the two latter connections.

21. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for passing a continuous electric current through and so heating one of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, and a circuit connecting the two latter connections.

22. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for heating one of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, a circuit connecting the two latter connections, and means tending to produce an alternating current in the circuit.

23. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for passing an electric current through and so heating one

of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, a circuit connecting the two latter connections, and means tending to produce an alternating current in the circuit.

24. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for passing a continuous electric current through and so heating one of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, a circuit connecting the two latter connections, and means tending to produce an alternating current in the circuit.

25. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for heating the filaments, two coils of a differential galvanometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, and a circuit connecting the two latter connections.

26. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for passing an electric current through the filaments, two coils of a differential galvanometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, and a circuit connecting the two latter connections.

27. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for passing a continuous electric current through the filaments, two coils of a differential galvanometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, and a circuit connecting the two latter connections.

28. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for heating the filaments, two coils of a differential galva-

nometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, a circuit connecting the two latter connections, and means tending to produce an alternating current in the circuit.

29. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for passing an electric current through the filaments, two coils of a differential galvanometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, a circuit connecting the two latter connections, and means tending to produce an alternating current in the circuit.

30. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for passing a continuous electric current through the filaments, two coils of a differential galvanometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, a circuit connecting the two latter connections, and means tending to produce an alternating current in the circuit.

31. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for heating one of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, a circuit connecting the two latter connections, and an induction-coil having its secondary winding in the circuit and its primary winding connected to an aerial wire and earth.

32. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for passing an electric current through and so heating one of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, a circuit connecting the two latter connections, and an induction-coil having its secondary winding in the circuit

and its primary winding connected to an aerial wire and earth.

33. The combination of two vacuum vessels, two conductors adjacent to but not touching each other in each vessel, means for passing a continuous electric current through and so heating one of the conductors in each vessel, two coils of a differential galvanometer, one coil being connected to the heated conductor in one vessel and the other coil being connected to the unheated conductor in the other vessel, a connection between the other pair of conductors, a connection between the coils, a circuit connecting the two latter connections, and an induction-coil having its secondary winding in the circuit and its primary winding connected to an aerial wire and earth.

34. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for heating the filaments, two coils of a differential galvanometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, a circuit connecting the two latter connections, and an induction-coil having its secondary winding in the circuit and its primary winding connected to an aerial wire and earth.

35. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for passing an electric current through the filaments, two coils of a differential galvanometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, a circuit connecting the two latter connections, and an induction-coil having its secondary winding in the circuit and its primary winding connected to an aerial wire and earth.

36. The combination of two vacuum vessels, a carbon filament in each vessel, a metallic cylinder in each vessel, surrounding but not touching the filament, means for passing a continuous electric current through the filaments, two coils of a differential galvanometer one coil being connected to the filament in one vessel and the other coil being connected to the cylinder in the other vessel, a connection between the other cylinder and filament, a connection between the coils, a circuit connecting the two latter connections, and an induction-coil having its secondary winding in the circuit and its primary winding connected to an aerial wire and earth.

37. At a receiving-station in a system of wireless telegraphy employing electrical oscillations

oscillations of high frequency a detector comprising a vacuum vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, a circuit outside of the vessel connecting the two conductors, means for detecting a continuous current in the circuit, and means

for impressing upon the circuit the received oscillations.

JOHN AMBROSE FLEMING.

Witnesses:

H. D. JAMESON,

A. NUTTING.

### DISCLAIMER.

803,684. *John Ambrose Fleming*, London, England. INSTRUMENT FOR CONVERTING ALTERNATING ELECTRIC CURRENTS INTO CONTINUOUS CURRENTS. Patent dated November 7, 1905. Disclaimer filed November 17, 1915, by the assignee *Marconi Wireless Telegraph Company of America*.

Enters this disclaimer—

"To the combinations of elements set forth in claims 1 to 6, inclusive, and 16 to 15, inclusive, respectively, of said Letters Patent, except as the same are used in connection with high frequency alternating electric currents or electric oscillations of the order employed in Hertzian wave transmission, and to the words in the specification: 'whether of low frequency or,' at page 2, lines 32 and 33; 'either,' at page 2, line 98; and 'or low-frequency alternating currents of,' at page 2, lines 98 and 99."

[*Official Gazette*, November 23, 1915.]

Disclaimer in Letters Patent No. 803,684.

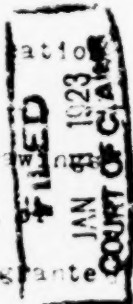
*Raymond + Sanford*

Plaintiff's Exhibit #34, Printed  
copy of Marconi British patent  
#7777 of 1900.

## PATENTS AND DESIGNS ACT, 1907.

It is HEREBY CERTIFIED by the Comptroller-General of Patents, Designs and Trade Marks that the annexed are true copies (as accepted) of the provisional specification lodged on the 26th April, 1900, in connection with the application of Marconi and another for Patent No. 7,777 of 1900, filed on the 26th April, 1900, and of the complete specification and drawings left in connection therewith on the 25th February, 1901.

It is also certified that the said complete specification was accepted on the 13th April, 1901; that the said provisional specification and complete specification and drawings were first printed and placed on sale in the Sale Branch of this Office on the 4th May, 1901; and that a Patent was granted in respect of the said application on the 25th June, 1901, and sealed as of the 26th April, 1900.



This certificate is issued for use in the United States of America.

WITNESS my hand this *18th* day

of April, 1917

*L. Thompson, Esq.*

Comptroller-General of Patents,  
Designs and Trade Marks.



BUILDINGS,

LONDON, W.C.

N<sup>o</sup> 7777

A.D. 1900

*Date of Application, 26th Apr., 1900**Complete Specification Left, 25th Feb., 1901—Accepted, 13th Apr., 1901*

## PROVISIONAL SPECIFICATION.

## "Improvements in Apparatus for Wireless Telegraphy."

We, GUGLIELMO MARCONI, Electrician, and MARCONI'S WIRELESS TELEGRAPH COMPANY, LIMITED, both of 28, Mark Lane, in the City of London, do hereby declare the nature of this invention to be as follows:

The object of this invention is not only to increase the efficiency of the apparatus hitherto employed, but also to so control the action as to cause intelligible communications to be established with one or more stations only out of a group of several receiving stations.

In the Specification of a former Patent No. 12,069 of 1896, a transmitter is described which consists of an induction coil, one terminal of the secondary circuit being connected to a metal sphere connected to earth and the other to a similar sphere connected to an insulated conductor which generally takes the form of a more or less vertical wire which may or may not terminate or have attached to it a metal body of extended surface giving it increased electrical capacity.

According to the present invention the vertical wire is connected to earth through the secondary winding of a transformer of a kind suitable for the transformation of very rapidly alternating electric currents and the primary of this transformer is connected to the spheres or terminals of the sparking appliance.

A condenser of suitable capacity is introduced in series with the primary or each end of the primary may be connected to one of the plates of two condensers of suitable capacity, the other plates of which are connected to the sparking appliance.

This device enables much more energy to be imparted to the radiator than heretofore, the approximately closed circuit of the primary being a good conservator and the open circuit of the secondary a good radiator of wave energy.

The arrangement works as follows:

On pressing the key and actuating the induction coil in order to produce a signal the condenser in circuit with the transformer is charged and subsequently discharges through the spark gap. If the capacity, the inductance, and the resistance of the circuit are of suitable values, this discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer, and induce similar oscillations in its secondary these oscillations being communicated to the elevated conductor.

The circuit of the elevated conductor should preferably be suitably attuned for this purpose.

The effect of these oscillations in the elevated conductor is to inductively affect similar distant conductors if the self inductance and capacity of the said conductors is of a suitable value or values.

At the receiving end a receiver is employed capable of being actuated by electrical oscillations of high frequency such as those described in the Specifications Nos. 12,426 of 1898, and 6982 of 1899.

The transformer which has been used at the transmitting station preferably consists of two windings of a few turns of insulated wire. The length of the wire and dimensions of the transformers may vary between wide limits, but satisfactory results have been obtained when working with vertical wires 100 feet long, with coils constituted of 10, 20, 30, and 40 turns of copper wire two millimetres in diameter, insulated with gutta percha or other suitable insulating material, each turn being about  $\frac{1}{4}$  inches in diameter, the primary and secondary being of the same thickness of wire and approximately of same length.

[Price 8d.]

*Improvements in Apparatus for Wireless Telegraphy.*

The condensers used in connection with these transformers were usually three or four pint Leyden jars. If the inductance of the induction coil used at the receiving station is varied, the inductance of the condenser circuit, or the capacity of the condenser, or both, should also be varied at the transmitting station.

In employing this invention to localise the transmission of intelligence to one out of several receiving stations one of the following methods is adopted. 5

The inductance coils at the receiving stations are wound with different lengths of wire and the self inductance and capacity of the transformer, condenser and elevated wire is accordingly varied over wide limits. It is found that if these factors are varied at the transmitting station until the electrical system composed of the elevated wire and its associated transformer circuit are in resonance with the receiving elevated wire and its induction coil and coherer connections of one of the receiving systems, that one alone, out of all the number of receiving stations responds, provided that the distance between the transmitter and receiver is not too small. In this manner each receiving instrument can be adjusted to respond only to the transmitter when the inductance of that transmitter has a certain value or values. 10 15

At the receiving station the period of oscillation of the system can be altered by altering the capacity and self-induction of the elevated conductor by varying its section or by connecting it to conducting bodies of large surface, or by introducing inductance coils in series with it, preferably at its highest extremity, or by varying the dimensions of the wire and the size of the induction coils used. 20

The period of the receiving system may also be altered by associating with the circuit of the induction coils condensers of suitable capacity, placed some in parallel and some in series with the primary and secondary. 25

At the transmitter the frequency may be varied in the same way as has been described for the receiver.

Dated this 26th day of April 1900.

G. MARCONI.

MARCONI'S WIRELESS TELEGRAPH CO. LTD. 30

By G. MARCONI,

Director.

S. FLOOD PAGE,

HENRY S. SAUNDERS,

HENRY W. ALLEN,

Secretary. 35

### COMPLETE SPECIFICATION.

#### "Improvements in Apparatus for Wireless Telegraphy."

We, GIULIO MARCONI, Electrician, and MARCONI'S WIRELESS TELEGRAPH COMPANY, LIMITED, late of 28, Mark Lane, and now both of 18, Finch Lane, in the City of London, do hereby declare the nature of this invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement; 40

The object of this invention is not only to increase the efficiency of the apparatus hitherto employed, but also to so control the action as to cause intelligible communications to be established with one or more stations only out of a group of several receiving stations. 45

In the Specification of a former Patent No. 12,046 of 1896, a transmitter is described which consists of an induction coil, one terminal of the secondary circuit being connected to a metal sphere connected to earth and the other to a conical sphere connected to an insulated conductor which generally takes the form of a wire or a vertical wire which may be of iron and terminate in or have 50

*Improvements in Apparatus for Wireless Telegraphy.*

attached to it a metal body of extended surface, giving it increased electrical capacity.

According to the present invention the vertical wire is connected to earth through the secondary winding of a transformer of a kind suitable for the transformation of very rapidly alternating electric currents and the primary of this transformer is connected to the spheres or terminals of the sparking appliance.

A condenser of suitable capacity is introduced in series with the primary or each end of the primary may be connected to one of the plates of two condensers of suitable capacity, the other plates of which are connected to the sparking appliance.

This device enables much more energy to be imparted to the radiator than heretofore, the approximately closed circuit of the primary being a good conservator and the open circuit of the secondary a good radiator of wave energy.

The arrangement works as follows:

On pressing the key and actuating the induction coil (in order to produce a signal) the condenser in circuit with the transformer is charged and subsequently discharges through the spark gap. If the capacity, the inductance, and the resistance of the circuit are of suitable values, the discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer, and induce similar oscillations in its secondary these oscillations being communicated to the elevated conductor.

The circuit of the elevated conductor should be suitably attuned for this purpose.

The effect of these oscillations in the elevated conductor is to inductively affect similar distant conductors if the self induction and capacity of the said conductors is of a suitable value or values.

At the receiving end a receiver is employed capable of being actuated by electrical oscillations of high frequency such as are described in the Specifications Nos. 12,326 of 1898, 6982 of 1899, and 25,186 of 1899.

The four circuits namely those including the primary and the secondary of the transformer in the transmitter and the primary and secondary of the transformer in the receiver should be so adjusted as to make the electric time period the same in each *i.e.* the product of the self induction multiplied by the capacity is the same in each case. But in lieu of the time periods being the same in each they may be harmonics of each other.

In employing this invention to localise the transmission of intelligence from a station to one only out of several receiving stations the time period of the circuits at each of these stations is so arranged as to be the same but different from those of the other receiving stations. If the time period of the circuits of the transmitting station are varied until they are in resonance with those of one of the receiving stations that one alone out of all the number of receiving stations will respond, provided that the distance between the transmitter and receiver is not too small.

The adjustment of the self induction and capacity of the circuits can be made in any convenient manner. As a practical guide to putting the invention in practice we subjoin the arrangements which we find work best.

Figures 1 and 2 are diagrams of the transmitter and of the receiver respectively, whilst Figure 3 shows a side view and Figure 4 an edge view of a transformer used at the transmitting station, and Figures 5 to 11 show various induction coils used at the receiving station.

*a* is a battery, *b* a Morse key, *c* a Ruhmkorff coil the primary of which is in circuit with the battery whilst the terminals of the secondary are connected to the primary *d* of a transformer one of the connections being through a condenser *e*, or there may be a condenser in both of the connections. The secondary *d'* of the transformer is connected to an aerial conductor *A* which may have at its top a metallic cylinder *f* and to earth or a capacity *E*. Between the secondary and the aerial conductor or it might be between the secondary and earth is sometimes inserted an inductance coil *g* having numerous coils and the connection is such

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that a greater or less number of turns of the coil can be put in circuit, the proper number to use being ascertained by experiment.

The receiver (Figure 2) consists of an aerial conductor A which may have a cylinder  $f^1$  at its top connected through an inductance coil  $g^1$  similar to  $g$  and through the primary  $j^1$  of an induction coil to earth or a capacity E; a small condenser  $h$  may be inserted in parallel with the primary  $j^1$ .

The secondary  $j^2$  of the induction coil is divided in the middle and has its inner ends connected to the plates of a condenser  $j^3$  while its outer ends are connected it may be through inductance coils  $g^2$  similar to  $g$  to a detector or coherer T; a condenser  $h^1$  may be inserted in parallel with the detector. The local circuit containing a battery cell B and relay or telegraph instrument R is connected through choking coils  $i^1$   $i^2$  to the plates  $j^3$  of the condenser.

The condensers  $h$   $h^1$  are preferably in the form of two metallic tubes separated by a dielectric and sliding telescopically on each other as in this way their capacity can readily be varied with accuracy to tune the circuits.

The following are details of arrangements which have been found to work best.

The cable used for the aerial conductor at either station and for the transformer  $d$   $d^1$  at the transmitting station is in all the examples given composed of seven strands of copper wire .889 m.m. in diameter. The aerial conductor at the receiving station is in each instance exactly similar to that at the transmitting station for the corresponding ~~tune~~.

The details of the transformers  $d$   $d^1$  are as follows:—

Transformer No. 1. The total length of the primary  $d$  including connections to spark gap and condenser is 3.46 metres and it is bent round a square  $d^2$  of insulating material of which the side is .17 metres long while the secondary  $d^1$  consists of two turns or squares one lying on each side of the primary (see Figures 3 and 4). The insulation of both primary and secondary consists of 1.25 m.m. of rubber and 1 m.m. of jute making a total thickness of 2.25 m.m.

Transformer No. 2 is exactly similar to No. 1 except that the total length of the primary  $d$  is 1.93 metres.

Transformer No. 3. The primary consists of ten turns of cable wound on a cylindrical core 10.16 c.m. in diameter; over this but separated from it by 2 m.m. of paper or other insulating material is wound the secondary also of ten turns.

Transformer No. 4. The total length of the primary  $d$  is 1.50 metres and it is bent round a square of insulating material  $d^2$  of which the side is .3048 metres long while the secondary  $d^1$  consists of 6 turns or squares three lying on each side of the primary in one layer. The insulation of both primary and secondary is the same as in No. 1.

Transformer No. 5. The primary consists of ten insulated wires each 1.5 metres long wound side by side in one layer and connected in parallel each wire making one turn on a square frame similar to that described for transformer No. 4.

Over this primary layer is put a covering of paper 1 m.m. thick, upon this is wound 48.64 metres of wire. The winding is arranged in layers, the number of turns in each successive layer being in the first layer that is in that nearest the primary 9, in the second 8, in the third 7, in the fourth 6, in the fifth 5, in the sixth 2.

The insulation is the same as in No. 1.

Transformer No. 6. The primary consists of seven wires wound side by side each wire making one turn on a square frame as used for transformer No. 4. The seven wires are joined in parallel and the length of each is 1.50 metres. Over this primary layer is wound a secondary 30.4 metres long, the winding being arranged in layers the number of turns in the successive layers being in the first layer 7 turns, in the second 6, in the third 5, in the fourth 4.

The transformers should be placed in an oil bath, especially if the turns are at all numerous.

The inductance coils  $g$   $g^1$  are of copper wire 6.25 m.m. in diameter wound on a cylinder 10.64 c.m. in diameter an interval of 2.28 m.m. being left between

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adjacent turns while the inductance coils  $g^2$  inserted in series with the secondary  $j^1$  of the induction coil at the receiving station are of copper wire, silk covered, of .19 m.m. diameter wound on cylinders .37 c.m. in diameter.

Figures 5 to 11 show details of the induction coils  $j^1$   $j^2$ .

- 5 These diagrams are greatly enlarged half longitudinal sections, but are not strictly to scale. In place also of showing the section of each coil or layer of wire as a longitudinal row of dots or small circles as it would actually appear, it is for simplicity shown as a continuous longitudinal straight line.

Induction coil No. 1 see Figure 5. The primary consists of 3.048 metres of  
10 silk covered copper wire .71 m.m. in diameter wound in one layer on a core 2.9 c.m. in diameter. Insulating material is wound over and on each side of this so as to make a cylindrical core 3.13 c.m. in diameter on which is wound the secondary each half consisting of 6.4 metres of silk covered copper wire .19 m.m. in diameter joined to 13.41 metres of silk covered copper wire .37 m.m. in diameter  
15 wound in the same sense as the primary, the thinner wire being over the primary and the thicker being beyond the ends of the primary.

Induction coil No. 2 see Figure 6. The primary  $j^1$  wound on a core .76 c.m. in diameter consists of 100 turns of copper wire .037 c.m. in diameter insulated with single silk and coated with paraffin wax, the secondary  $j^2$  is of copper  
20 wire .019 c.m. in diameter insulated with single silk covering and is wound over the primary, commencing in the middle and in the same sense as the primary. Each half of the secondary is in layers of the following number of turns: first layer 77, second 49, third 36, fourth 41, fifth 40, sixth 37, seventh 34, eighth 31, ninth 28, tenth 25, eleventh 22, twelfth 19, thirteenth 16, fourteenth 13,  
25 fifteenth 10, sixteenth 7, seventeenth 4, making 500 in all.

Induction coil No. 3 see Figure 7. The primary consists of 3.048 metres silk covered copper wire .19 m.m. in diameter and the secondary 30.48 metres long of silk covered copper wire .1 m.m. in diameter wound in one layer on a core 4 c.m. in diameter the primary being in one layer outside the secondary.

Induction coil No. 4 see Figure 8. The primary consists of 3.048 metres silk covered copper wire .37 m.m. in diameter wound on a core 2.9 c.m. in diameter and inserted in a tube  $j^2$  of 4 c.m. external diameter on which is wound the secondary of 27.432 metres silk covered copper wire .12 m.m. in diameter, the  
30 break at the middle of the secondary being over the middle of the primary.

Induction coil No. 5 see Figure 9. The secondary consists of 7.315 metres of wire wound in one layer on a tube 5 cms in diameter and is divided at its middle point, the wire being .12 m.m. in diameter single silk covered.

There are two primaries each consisting of 2.75 metres of wire .7 m.m. in diameter wound on tubes 6.5 cms external diameter. The two primaries are  
35 placed symmetrically side by side one over each half of secondary and are joined in parallel.

Induction coil No. 6 see Figure 10. The secondary consists of 48.64 metres of single silk covered copper wire .37 m.m. in diameter wound on a tube of 9.0 cms diameter in one layer and is cut at its middle point. Symmetrically over the  
40 middle portion of the secondary is wound the primary 1.64 metres long of wire .7 m.m. diameter, single silk covered.

Induction coil No. 7 see Figure 11. The primary consists of four wires each 3.04 metres long wound in four layers and joined in parallel, the layers being  
45 one under the other, the wire is .71 m.m. in diameter insulated with a single covering of silk.

The secondary which is wound on a tube of 3.3 cms external diameter consists of 11.23 metres of wire .12 m.m. diameter insulated with a single covering of silk. The secondary is divided at its middle point and the primary is placed  
50 symmetrically inside the secondary.

The following table give the adjustments, those details opposite any tune in the transmitting station table being of course used in connection with those opposite the same tune in the receiving station table.

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## TRANSMITTING STATION.

Tune	Aerial conductor	Transformer d d <sup>1</sup>	Inductance Number of turns of <i>g</i> included	Capacity in microfarads <i>e</i>	Length of spark in millimetres	
N 1	36.576 metres of cable	N 1	None	006934	3	
N 2	ditto	N 1	45	016395	4	
N 3	ditto	N 2	None	004112	3	5
N 4	ditto	N 2	100	016849	4	
N 5	Zinc cylinder 9.144 metres long, 1.524 metres indiameter hoisted 30.48 metres above ground	N 2	None	001600	12.5	
N 6	30.48 metres of cable	N 3	None	000573	4	
N 7	Four vertical wires each 48.6 metres long connected together at top and bottom but kept apart throughout their length by being suspended from the arms of a wooden cross each arm of which is 4 metres long	N 4	None	016	6	
N 8	One vertical wire 48 metres long	N 5	None	007	6	10
N 9	One vertical wire 30.4 metres long	N 6	None	0026	5	

*Improvements in Apparatus for Wireless Telegraphy*

## RECEIVING STATION.

Tune	Induction coil	Capacity in microfarads of		Inductance introduced in	
		$k$	$k_1$	$g$ Number of turns	$g^1$
N <sup>o</sup> 1	N <sup>o</sup> 1	Omitted	Omitted	None	None
N <sup>o</sup> 2	N <sup>o</sup> 1	Omitted	00004	45	None
5 N <sup>o</sup> 3	N <sup>o</sup> 2	00046	Omitted	Up to 21 may be inserted	None
N <sup>o</sup> 4	N <sup>o</sup> 2	00046	Omitted	100	2 coils of 15.24 metres at each end of secondary.
N <sup>o</sup> 5	N <sup>o</sup> 3	Omitted	Omitted	None	None
N <sup>o</sup> 6	N <sup>o</sup> 4	Omitted	Omitted	None	None
N <sup>o</sup> 7	N <sup>o</sup> 5	Omitted	Omitted	None	None
10 N <sup>o</sup> 8	N <sup>o</sup> 6	Omitted	Omitted	None	None
N <sup>o</sup> 9	N <sup>o</sup> 7	Omitted	Omitted	None	None

NOTE. In tune No. 9 a small condenser having an approximate capacity of 000008 microfarad is inserted between the lower end of the receiving aerial conductor and the induction coil.

15 It will be observed that both the transmitter and the receiver are the same for tunes 1 and 2 and that when the capacity of the condenser  $c$  is varied, the two stations can be brought into tune by including 45 turns of each of the coils  $g$   $g^1$  and by introducing a condenser  $k^1$  of small capacity in parallel with the coherer T. Similarly the transmitter and receiver are the same for tunes 3 and 4 and when the capacity of  $c$  is varied, the stations are tuned by including 100 turns of each of the coils  $g$   $g^1$  and also by including the two coils  $g^2$ .

20 Tunes Nos. 7 and 8 give very good signals over a distance of 190 miles.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what 25 we claim is:—

1 A transmitter for electric wave telegraphy consisting of a spark producer

*Improvements in Apparatus for Wireless Telegraphy.*

having its terminals connected through a condenser with one circuit of a transformer the other circuit being connected to a conductor and to earth or a capacity the time period of electrical oscillations in the two circuits being the same or harmonics of each other.

2. A system of electric wave telegraphy in which both the transmitter and the receiver contain a transformer the time period of electrical oscillations in the four circuits of the two transformers being the same or harmonics of each other.

3. A system of electrical wave telegraphy in which both the transmitter and the receiver contain a transformer one circuit of which is a persistent oscillator and the other a good radiator or absorber of electrical oscillations all four circuits having the same time period or being harmonics of each other substantially as described.

4. Apparatus for wireless telegraphy substantially as described and illustrated in the drawings.

Dated this 25th day of February 1901.

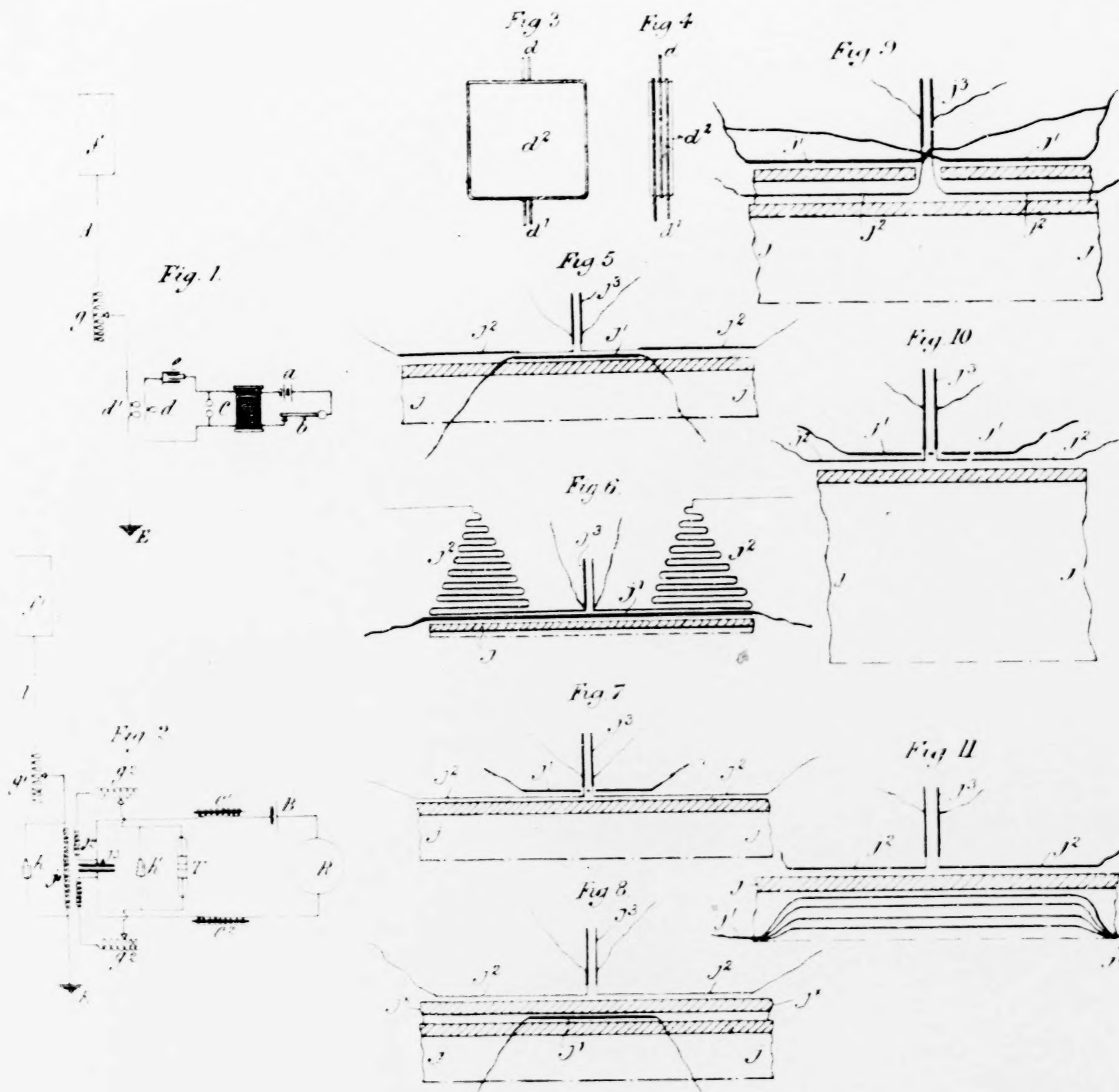
G. MARCONI

MARCONI'S WIRELESS TELEGRAPH CO., LD.

By Carpmael & Co.,  
Agents.

Redhill. Printed for His Majesty's Stationery Office by Lewis & Mackenzie, Ltd.

[Wt. 57-250/12/1010]



[fol. 2256] PLAINTIFF'S EXHIBIT No. 35

ROYAL COURTS OF JUSTICE,  
Friday, 24th July, 1914.

IN THE HIGH COURT OF JUSTICE. CHANCERY DIVISION

Before

MR. JUSTICE EVE

and

PROFESSOR BERTRAM HOPKINSON (Assessor)

G. MARCONI AND MARCONI'S WIRELESS TELEGRAPH COMPANY,  
LIMITED,

v.

THE HELSBY WIRELESS TELEGRAPH COMPANY, LIMITED

[From the Shorthand Notes of Cherer & Co., 8, New Court,  
Carey Street, W. C.]

MR. A. J. WALTER, K.C., and MR. J. HUNTER GRAY (instructed by Messrs. Coward & Hawksley, Sons & Chance) appeared for the plaintiffs.

MR. COURTNEY TERRELL and MR. ARTHUR JAFFE (instructed by Messrs. Kenneth Brown, Baker, Baker & Co.,) appeared for the Defendants.

#### JUDGMENT

MR. JUSTICE EVE: This action was commenced on the 18th of October, 1912. At that date, and down to the expiry on the 25th day of April last, the plaintiffs were the owners of Letters Patent No. 7777 of 1900 for an invention of "improvements in apparatus for wireless telegraphy". They allege that the defendant infringed the said Letters Patent in 1911 by the construction and installation of an apparatus [fol. 2257] on board four steamships belonging to the London & North Western Railway Company. The defendants deny that they have infringed; and they allege that the Letters Patent are invalid by reason of certain prior publications; and on these two issues the case has been tried.

The area of conflict has been considerably curtailed, and the points in conflict greatly reduced by the fact that in 1911 the Letters Patent upon which the plaintiffs are suing were construed; and many of the objections raised by the Defendants in their Pleadings here were dealt with by Lord Parker (then Mr. Justice Parker) in an action brought by the Plaintiffs against other defendants. The apparatus used by the defendants in that action was held to be an infringement of the Plaintiff's patent, and it is admitted that the apparatus complained of in this action is for electrical purposes identical with the apparatus so held to be an infringement, except for the introduction into the primary circuit of two additional spark gaps and a through charging coil—but as the presence of the coil is consequent on the introduction of the two spark gaps, there is nothing substantial in that (See Questions and Answers Nos. 2457 and 2461).

The short point, therefore, on the issue of infringement which I have to decide is whether, by the introduction of the two spark gaps, the Defendants have produced an apparatus which does not come within the scope of the Plaintiff's patent. The object of the two additional spark gaps is the reduction of the length of the primary wave train; and that they do bring about some reduction is, in my opinion, established by the evidence. Indeed, that such is the case is not disputed by the plaintiffs; it is mainly a question of degree. The defendants put forward and rely on the Exhibit J. S. 9 as demonstrating diagrammatically the reduced length, of the primary wave train consequent on the introduction of the spark gaps; and they insist that optical experiments go to confirm the accuracy of the photographic material which forms the basis of that diagram. In estimating the credibility to be attached to J. S. 9—that is to say, in considering how nearly it approaches to an exact reproduction of facts—one has to give weight not only to the obvious physical difficulties of accurately reproducing by photography phenomena the duration of the existence of which is measured by millionths of a second; and the [fol. 2258] agencies employed in the reproduction; that is to say, such things as the sensitiveness of the photographic plate, and the actinic value of the metal constituting the spark gaps, but also the following facts admitted or proved in the course of the trial. (1) That the Defendants' installation works satisfactorily over the requisite distances; (2)

that it is not wasteful of energy; (3) that the coupling of the two circuits is a loose one in the neighborhood of 2 per cent, and certainly not exceeding 5 per cent; (4) that with loose coupling the transfer of energy must be in small doses, something like 3 per cent per oscillation; and (5) that substantially the whole of the energy in the primary has been in fact transferred to the secondary in the Defendants' apparatus when the primary has ceased to oscillate. The conclusion to which a consideration of these matters has led me, is that J. S. 9 cannot be accepted as quantitatively reliable. The alternative of accepting it as accurate leaves one face to face with more than one problem, to which I cannot find a satisfactory answer in the Defendants' evidence. For example (1) How can a large proportion of the energy be transferred from primary to secondary in  $3\frac{1}{2}$  oscillations with a coupling of less than 5 per cent; (2) If only that percentage of the energy which corresponds to this coupling is transferred, how can the Defendants' apparatus be either efficient or non-wasteful? and (3) If the whole of the energy is not transferred, what becomes of it? But as I have already stated, I am satisfied that the presence of the spark gap does substantially reduce the length of the primary wave train; and that after the primary has ceased oscillating the secondary continues to oscillate for a number of periods, and to radiate the pure wave of the aerial. The Defendants claim that the result of this is to improve the working of the installation, and that the cutting off or shutting down of the primary eliminates what has been called the double humped curve produced when surplus energy is returned from the secondary to the primary, as it can be when the primary is persistently oscillating while the secondary is radiating.

I think this may be the case; but I do not think it affects the real question which I have to answer. I think that question may be thus stated: Is it an essential feature of Marconi's invention that the primary should oscillate so that as energy is radiated by the aerial the primary will persistently replenish the secondary with at least an equivalent amount of energy, and thereby maintain the radiating secondary? I do not think it is. In both the Plaintiffs' and the Defendants' installations, the primary oscillations die down before the secondary oscillations are finished; and in this sense the question resolves itself into one of degree, dependent largely on the character of the

radiation employed. With a good radiator radiating in a single swing, a very large percentage of the energy transferred, the oscillations of the secondary must die down very quickly after those of the primary have died down; and in such an installation the primary may well be said not only to build up oscillations in the secondary, but thereafter to maintain them, and to be in the true sense the reservoir on which the secondary is persistently drawing for energy to replace that which is being contemporaneously radiated.

But with the radiators of, what I may perhaps call, more conservative capacities, the necessity for persistent maintenance is proportionately reduced; and although when such radiators are employed, the function of the primary is perhaps rather to build up than to maintain the secondary oscillations, it nevertheless does in fact both build them up and maintain them.

The Defendants rely greatly on these passages in Lord Parker's Judgment, wherein they claim that he expressly treats the maintenance of the secondary oscillations by the persistence primary oscillations as of the essence of the invention; but these passages must be read in relation to the particular infringement with which the court was then dealing; and in my opinion they are not equivalent to a construction of the patent which would have precluded the patentee from claiming protection for installations embodying radiators in which the oscillations could be built up and maintained without the necessity of keeping the primary persistently oscillating.

I think, notwithstanding the great ability which has been displayed in endeavoring to lead me to a different conclusion, that the Defendants have in substance appropriated the invention described in the Plaintiffs' Letters Patent, and that in the construction of their apparatus they have only introduced such modifications as are within Marconi's specification, and covered by his claim. I hold, therefore, that their apparatus was an infringement of the Plaintiff's patent.

[fol. 2260] This conclusion disposes of the Defendants' suggestion that their apparatus is Fig. 4 of Lodge's specification of 1897; but with regard to that figure, and the working of the apparatus there depicted, I am advised by the Assessor—whose valuable assistance throughout I take this opportunity of acknowledging—that Mr. Swinburne's evidence—illustrated in J. S. 16—is to be preferred to that of

Dr. Erskine Murray. It is possible that Lodge made an invention when he suggested, in connection with Fig. 4, that he would charge the aerial, and would then cut it off from the charging agent as rapidly as possible, leaving it free to swing independently and the Defendants may have taken this invention; but even so, that does not mean that they have not also taken Marconi's invention, which relates to the nature of the charging agent; and can quite well be combined with Lodge's invention.

I do not think it is necessary to dwell at length on that part of the case which is concerned with the alleged prior publications. In my opinion, no evidence has been adduced in this case which qualifies in any way the conclusions at which Lord Parker arrived upon the question of Tesla's alleged anticipations, and which are to be found at lines 36 to 49 on page 213 of 28 Reports of Patent Cases. Nor, as a matter of construction, do I think that the passage on page 45 of the documents referred to in the Particulars of Objections, where the use by Dueretot of the Oudin resonator is dealt with, refers to anything else than a user for the purpose of tuning transmitter and receiver; and, as Dr. Erskine Murray admits, the passage of page 51 covers the same ground only. His evidence on this alleged anticipation is well summed up on page 243 of the Notes, where at Question 2947 he is asked: "Aye or no", do you suggest this taught the world the Marconi invention". And he replies: "I say it might teach the world—but there is always the teacher and the taught." That is not the sort of evidence on which I should be justified in holding that these passages relied on by the Defendants disclose an anticipation; and I decline so to do.

In my opinion, the Plaintiffs are right. They are entitled to a declaration that the Defendants' apparatus was, at the date of the Writ, and thereafter down to the 25th of April last continued, an infringement of the Letters Patent No. 7777 of the year 1900; to an inquiry as to the damages [fol. 2261] sustained by them in consequence of such infringement; and to the costs of the action down to and including this Judgment, to be taxed as between solicitor and client. The subsequent costs will be reserved; and there will be liberty to apply.

Mr. Hunter Gray: I ask your Lordship for a certificate that the Particulars of Praises are reasonable and proper?

Mr. Justice Eve: Yes, with one exception.

Mr. Courtney Terrell: It is with one exception.

Mr. Hunter Gray: Yes.

Mr. Justice Eve: With that exception.

(Endorsed as follows):

In the High Court of Justice, Chancery Division, Royal Courts of Justice, 24th July, 1914. Before Mr. Justice Eve and Professor Bertram Hopkinson (Assessor). G. Marconi and Marconi's Wireless Telegraph Company, Limited, vs. The Helsby Wireless Telegraph Company, Limited, Judgment.

Coward & Hawksley, Sons & Chance, 30 Mincing Lane, E. C., Plaintiff's Solicitors.

[fol. 2262] PLAINTIFF'S EXHIBIT No. 36

Civil Tribunal of the Seine

(3RD CHAMBER)

24th December, 1912

Under the Presidency of M. BONJEAN

LETTERS PATENT.—WIRELESS TELEGRAPHY.—MARCONI'S SYSTEM.—PATENTABLE INVENTION.—FRESH COMBINATION OF MEANS ALREADY KNOWN.—SYNCHRONIZATION OF THE CIRCUITS.—SYNCHRONIZATION OF THE WAVES.—ANTICIPATION CLAIMED.—INCONTESTABILITY.—INFRINGEMENT.—ELEMENTS.—EMPLOYMENT OF THE CHARACTERISTIC PROCESS OF AN INVENTION.—SLIGHT MODIFICATION.—SUBSTITUTION OF EXCITATION BY DERIVATION FOR COUPLING BY INDUCTION.—INOPERATIVE CIRCUMSTANCE.—JUDGMENT.

1. *A patentable invention is constituted by the formation of a new device leading to a new industrial result, even though the same may be obtained by the combination of means that are already known and of elements that exist separately and are public property.*

*From this point of view there are therefore grounds for acknowledging the appliance devised by Marconi for improving wireless telegraphy and which was the subject matter of his patent of 3rd November, 1900, No. 305,060, as*

containing the characteristics of a patentable invention, which device contains the following characteristic features: (1) The establishment of four circuits in tune with each other, that is, having all four the same period, the product of the self-induction by the capacity being the same in each of them, but with varying factors of multiplication, so that each of the four circuits is appropriated for its own particular function; and (2) as a consequence of the tuning of these four circuits in resonance with each other: synchronization between the transmitter and the receiver, synchronization between the primary circuit and the secondary circuit, on each side, such synchronization giving as a result a selectivity, in virtue of which the receiving station can only receive signals from the station or stations with which it is in tune.

2. There cannot be regarded as an anticipation opposable to this invention:

Either the device of Lodge's patent No. 11,575 of 1897, which contains at the receiving station only two circuits, which are not adjustable and consequently not tunable, i. e., which it is impossible to bring into resonance.

Or that of Ducretet's patent containing one single circuit with transmitting antenna directly connected with the spark producer and foreign to the principle of syntonization;

Or the system of Braun's patents of 1899 and 1900, which is based upon two untuned circuits and one transmission, and not upon four circuits syntonized two and two in two groups, which are in their turn syntonized with each other. [fol. 2263] Or the Tesla patents of 1891, 1896 and 1897 which have in view only the transmission of electric energy and not wireless telegraphy, and which in any case are foreign to the idea of syntonization, which is the basis of the Marconi system;

Or finally the 1898 patent of Marconi himself, that lapsed in 1910 owing to non-payment of the fee, which patent only contained two circuits for the receiver, and was likewise foreign to the idea of syntonization.

3. When, as in the case of Marconi's, a patent covers a combination of parts or a process producing new and useful results, anyone producing the same results by making use of the principal parts of the combination or of the process infringes the patent, even though he may have modified the combination or the process by the omission of an unimpor-

*tant part and by substituting therefore another equivalent part.*

*In particular, there should be considered as an infringement of the process and of the apparatus for wireless telegraphy devised and patented by Marconi, an arrangement for wireless telegraphy founded upon syntonization, which is the fundamental basis of the Marconi system for the reception of Hertzian waves, even though such syntonization should be obtained by means of indirect excitation by derivation instead of being by coupling through induction or in other words by the substitution of an auto-transformer (in particular a Oudin resonator) for the transformer made use of by Marconi.*

Société Marconi v. Société Générale des Transports Maritimes, Compagnie Radiotélégraphique and Société Radio-électrique

#### The Tribunal

As regards the Form:

In view of the analogy between the actions, consolidates them in order to deal with the whole matter by one single decision.

Receives the Compagnie Radiotélégraphique as Plaintiffs in the cross-action.

Certifies to Legru that he leaves to the Court the question of infringement.

Certifies to the Société Générale des Transports Maritimes that that Company reserve their right to claim damages in the event of the substitution of the rented apparatus causing interference with its working.

As regards the Substance:

Whereas the Plaintiff Company is the holder of letters patent applied for on 3rd November, 1900, and granted on 1st February, 1901, under the number 305,060 for an improvement in wireless telegraphy:

Whereas the Plaintiffs allege that in violation of their rights the Société Générale des Transports Maritimes had [fol. 2264] provided some of their steamers with wireless telegraphy apparatus stated to be an infringement of the patent:

Whereas in consequence of an order made by the President of this Court dated the 12th October, 1911, upon a

summons dated 24th October, 1911, issued by Hardy, Bailiff, assisted from the technical point of view by M. Hubert, Engineer, a seizure for infringement was effected upon the steamer "Sidibrahim," of the Compagnie des Transports Maritimes, at anchor in the harbour of La Joliette at Marseilles, of apparatus belonging to wireless telegraphy plant alleged to be infringements, together with a sketch plan of the said installations, such seizure being effected in the absence of the operator of the wireless telegraphy cabin:

Whereas it was stated to the Bailiff by the Captain that other identical appliances were in existence, being installed upon three other steamers of the same company at anchor in the harbour of Marseilles—the "Italie," the "Parana" and the "Algérie";

Whereas it is not disputed that the apparatus the subject of the action had been installed with the concurrence of the Société Française Radiotélégraphique, which is, in fact, the owner of the same;

Whereas the Plaintiffs consequently claim jointly and severally against their opponents: In respect of the infringement applying for the confiscation of the apparatus seized, that the Société Française Radiotélégraphique be restrained from constructing, installing, exhibiting and offering for sale apparatus constituting an infringement of the patent; to an amount to be fixed by reference;

Whereas on their part the Société des Transports Maritimes à Vapeur, in the principal action, claim against the Société Radiotélégraphique on the ground that the latter is the owner of the articles seized, that the latter should be ordered to indemnify the former in respect of any judgments which might be granted against them in favour of the Marconi Company;

Whereas by their Statement of Claim of 14th October, 1912, the Compagnie Générale Radiotélégraphique claim that the Marconi patent shall be declared void on account of lack of novelty, alternatively, that same has lapsed owing to not having been worked in France during the three years following the application for the patent granted; and, finally, that the application should be rejected on account of the seized articles or apparatus not being an infringement of the Marconi patent.

Whereas the Plaintiffs, by virtue of the aforesaid order, which permitted the seizure at Marseilles for the same reasons and pursuant to the Summons of Guérard, Bailiff at Havre, under date of the 8th October, 1911, with the technical assistance of M. Noël, Engineer in Arts and Manufacturers, had a seizure effected of various appliances for wireless telegraphy serving the steamer "Apache," belonging to Legru, such appliances at the time in question not being in the wireless cabin on board, but in a warehouse on shore:

[fol. 2265] Whereas the Bailiff found upon one of the appliances a plate bearing the inscription "Société Française Radioélectrique," and whereas in consequence the Marconi Company claim that the Société Radioélectrique should be subjected to the same penalties as those above mentioned against the Société Radiotélégraphique and the Société des Transports Maritimes à Vapeur:

Whereas Legru claims against the Marconi Company and the Société Radioélectrique that the latter, in the event of the former succeeding in the action, should reimburse to him the sum of 5,000 francs for the cost of the seized appliances and the expense of installing them on board the "Apache," and whereas the Société Radioélectrique in like manner with the Société Radiotélégraphique claims that the Marconi patent shall be declared void, and in any event to have lapsed on account of not having been worked in France within the prescribed period, and finally, that there is no infringement on account of differences existing between the patented device and the appliances seized:

Whereas henceforward the discussion is carried on, in like manner, with regard both to the arguments between the Marconi Company on the one hand and their two groups of opponents on the other, no useful purpose being served in following these discussions, which are necessarily somewhat abridged in comparison with the important arguments which have not been considered too lengthily in view of the task to be achieved, on the one hand to demonstrate the perfect validity of the patent and on the other to demonstrate its nullity on account of anticipations, and, alternatively, that it has lapsed on account of not having been worked, and finally, in the further alternative, the absence of infringement on account of sufficient differences between the patented device and the two sets of

apparatus not being identical, which were seized, the one at Marseilles against the Société des Transports Maritimes à Vapeur and their owner the Société Radiotélégraphique, and the other at Havre against Legru and the Société Radioélectrique, which supplied the same to him.

Whereas it is further necessary, prior to proceeding to the examination of the claims of the opposing parties, to reserve the double claims of the Marconi Company, with respect to each of the two groups of Defendants, to amend their original claims for damages by extending them to those acts of infringement which took place subsequent to the application; and of the Société Radioélectrique to the insertion of any decision to be given in their favour in fifteen newspapers by way of damages:

Whereas it is advisable to divide the study of the questions submitted to the Court into five parts: (1) History of wireless telegraphy, and the research which is indispensable before discussion of the terminology most commonly employed in this special branch of applied science; (2) Examination of the various Marconi patents and thereafter the [fol. 2266] evolution of his scientific effort; (3) An analysis of all the cases of anticipation claimed against the patent of 1900, which is the only one that is set up in the present action; (4) An examination of the complaint of non-working within the prescribed period; (5) A comparison of the devices alleged to be infringements of the Marconi apparatus and consequently an eventual justification of the charge brought against the Defendants.

#### Part First—History.

As regards the First Portion:

Whereas logically the name of wireless telegraphy should be applied to all processes employed by human ingenuity for the rapid transmission of thought from one place to another without any material link between the point of transmission and that of reception:

Whereas such was last century the "Chappe" telegraphy and at the present day optical telegraphy, which is at times the successful rival of wireless telegraphy properly called according to current terminology:

Whereas this admirable discovery was the result not of chance, like the electric battery, which was due to a current of wind that was vivified by the genius of Galvani, but was

a practical application of observations of purely speculative science;

Whereas, without recalling the researches of Henri about 1839 upon the inductance of electric circuits, it may suffice to say that wireless telegraphy is the industrial result of the theory of Hertzian waves, which is itself due to the development of Maxwell's discoveries;

Whereas, indeed, this scientist, while rejecting the idea of distant effects, necessarily arrived at the result of viewing electric and magnetic phenomena as being merely deformations of the interposed medium;

Whereas a fresh experimental fact brought about a confirmation of this hypothesis by leading to a theory which embraced together electricity, magnetism and light.

Whereas indeed, all electric or magnetic magnitudes can be connected with mechanical magnitudes, so that with the three fundamental mechanical units, length, mass and time, they can be measured, *i. e.*, the system designated C. G. S. or centimetre mass of a gram, and, second,

Whereas in seeking the value of the ratio existing between the electro-magnetic and electrostatic units, Maxwell obtained the figure of 300,000 kilometres per second, *i. e.*, the speed of light, from which he reached the conclusion that there was not merely analogy but identity between the vibrations recognised by experience under their double electro-magnetic and luminous form, the former being the result of an alternating current and the latter of a source of light.

Whereas the scientist Hertz by his experiments confirmed the bold hypothesis of Maxwell, and whereas he brought out this scientist's truth, *viz.*, that an electric source in dis- [fol. 2267] charging produces oscillations which are communicated, such as sound and light, to that mysterious ether in infinite space of which our atmosphere is not part, which is as imponderable as an absolute vacuum as it in no way disturbs the motions of heavenly bodies, and which nevertheless is so thoroughly existent as the necessary connecting link of matter that it scientifically permits the slightest noise, the smallest ray of light, the least movement imparting agitation to it, such as an electric impact, to proceed in every direction of a sphere, the point of departure of which is the centre, into the infinitude of time and space;

Whereas this motion is produced by means of waves analogous to those called forth by a body falling upon a

liquid surface which is immediately covered with circles, the centre of which is the point where the body disturbed the liquid, and which proceed ever widening, but diminishing in height towards the limits of the liquid sheet;

Whereas the special character of these waves in the ether as well as in the liquid, in spite of what in the latter case might be thought, is that the translateral progressive movement referred to above is only apparent; and whereas as a matter of fact in the trite example mentioned previously of a disturbed liquid sheet, a float upon the surface of the moving liquid does not alter its position in a horizontal or lateral direction, but merely rises on the apparent passage of the wave in order to descend again until it again rises under the action of the subsequent undulation; and that thus undulations can be compared to a palpitation without any lateral displacement of the fluid which is disturbed by any impact.

Whereas this special motion is called oscillation, whilst the motion of the waves from the centre to the periphery without displacement and without any transport of the fluid is called radiation; and whereas the length of time which a molecule raised by the undulation takes to re-descend to its point of departure, that is to say, the duration of the oscillation, is called the period of this oscillation; and whereas, finally, the wave length is the distance covered by the motion of radiation during the period of oscillation;

Whereas, in order more readily to study the waves bearing his name, Hertz wished to create short waves by increasing the frequency of the oscillations, which he achieved by the radiator that is also called after him and which is nothing but an emitter of waves in the ether;

Whereas, in order to reveal the waves that the eye could not perceive, Hertz constructed by means of a spiral of metal wire an open circle or detector to which he imparted peculiar sensitiveness by utilising, as far as possible, the very interesting principle of resonance, whence the name of resonator given to this apparatus; and whereas, as a matter of fact, just as a pendulum which is set in motion by a first impulse moves with increasing amplitude of oscillation if fresh impulses at each oscillation add their effect to [fol. 2268] the first one at intervals of time corresponding with the period of oscillation, *i. e.*, at the moment when the pendulum is moving in the direction in which the first impulse had driven it, whilst apart from this condition the

successive impulses, instead of exerting a cumulative effect, would destroy the effect already accomplished, just as in acoustics, by prolonging, for instance, the vibration of a note upon a string in the neighborhood of other strings of various tone values, the string having the same tone value as the one set in action or its octave, will in its turn vibrate in unison or in octave; whereupon Hertz concluded that if his receiver was regulated to the same period as the radiator, the series of waves created in the ether by the latter would have a cumulative effect upon the receiver and would make it more sensitive to its action;

Whereas Hertz was thus able in 1889 to demonstrate experimentally the correctness of Maxwell's theory and to show how the waves developed in the ether by an oscillating electric current manifested their presence by a spark, which was the first step towards wireless telegraphy;

Whereas Branly in his turn gave a fresh impulse to the discovery, that was as yet unsuspected, by utilising for the first time, in order to reveal the Hertzian waves, a coherer consisting of a glass tube filled with iron filings; whereas this tube is, as a matter of fact, a bad conductor, but becomes a good conductor when, under the action of an electric current, the particles cohere; and whereas Branly placed this tube in a special current, that was interrupted by this tube, which remained sensitive to the waves, so that when the waves met the coherence being produced, the current was re-established and operated the needle of a galvanometer which was also introduced into the circuit and which thus signalled the presence of the waves; whereas, of course, this effect being produced, care was taken to destroy the coherence by means of a suitable tap, thus interrupting the current and fitting the apparatus for again giving notice of the passage of fresh waves;

Whereas in 1892 Crooks was the first to suggest that the foregoing discovery might well lead to wireless telegraphy, and whereas Marconi, with the same idea in his mind, brought it to a sufficient degree of perfection to take out his first patent on 2nd June, 1896, thus inaugurating the marvellous invention which from this point of view makes him worthy of imperishable memory;

Whereas after these indispensable preliminaries defining the phenomena and the expressions, without a knowledge of which the discussion could not be followed, it is further

necessary to explain some new terms that will appear in the patents which remain to be examined;

Whereas in the first place in the matter in question one of the first functions is carried out by appliances usually called coils and sometimes designated transformers which are in principle composed of two concentric windings of metallic wires conducting electricity; whereas the first of [fol. 2269] these windings forming the primary circuit is therefore called the primary, whilst the second winding, called the secondary, constitutes the second or secondary circuit formed by induction or induced, when it is cut by lines of force of the magnetic field created by the passage of an electric current passing through the primary;

Whereas a distinction is made between a continuous current and an alternating or alternate current which resumes its intensity after having changed its direction and returning to zero; whereas the voltage of a current is the measure of the pressure of electricity in the current, whilst its intensity is the volume of current per unit of time; whereas the resistance is the difficulty experienced by the current in passing through a conductor under a definite electric pressure or voltage; whereas this resistance is usually produced by a coil surrounded by a wire and placed within the circuit where it produces a kind of throttling that permits of the volume of the current being varied;

Whereas the current which penetrates into a conductor does not at once acquire a stable condition on account of the expenditure of energy necessary for the creation of the magnetic field surrounding every electric conductor, which constitutes a real induction of the current upon itself; whereas this delay is called self-induction, which is very strong in coils with a core of soft iron; hence the term self-induction coils is applied to those with an electro-magnet or those without such a part, but any that are intended to retard the normal condition of the current;

Whereas induction is a phenomenon by means of which any electric circuit in the neighbourhood of a circuit, whether approaching or moving away from the same, gives rise to a current in the second circuit, and furthermore if these neighbouring currents are mobile, and if one of them is fed with alternating currents as already stated, a secondary current is produced by induction; whereas this phenomenon is the basis of transformers, the industrial

function of which has become so considerable, as they work of themselves, automatically; whereas they consist of more or less concentric coils; whereas the first winding, called primary, receives two alternating currents, which by induction give rise in the second winding, called the secondary, to another current bearing the same name, which is also alternating, varying in its voltage, its intensity, according to the characteristics of the windings of the coil, and is in any case induced, that is to say, formed by induction, when it is cut by lines of force of the magnetic field created by the passage of the primary current; whereas the classic type of this transformer is the Ruhmkorff coil, the primary of which is actuated by a continuous current, but which is rendered alternating, and the secondary of which gives sparks;

Whereas the condenser consists of two electric surfaces separated by an insulating coating, and is intended for the [fol. 2270] purpose of condensing and storing electric energy in order to supply it when required; whereas the faculty of storing electricity is called capacity;

Whereas if within an electric circuit comprising any source of electricity a conductor, a resistance, is connected to a condenser of a certain capacity and a self-induction coil; and if, on the other hand, the condenser is connected to a suitable source of electricity, and if in the condenser there is a gap, there will be a spark discharge, and according to the relations of resistances, of the capacities, and of the self-induction, there will be discharges of varying nature, continuous or oscillating, flowing alternately from one pole to the other;

Whereas, however, in this circuit the time of oscillation and consequently the period of the waves which will arise by the discharge of the spark are proportional to the product  $LC$ , that is of the capacity  $C$  multiplied by the self-induction  $L$ , according to Thomson's formula;

Whereas by the application of this principle, by varying the relations of the elements of the equation, it is possible to tune the periods of oscillation, so that interested circuits may be combined, which is precisely the condition of receptivity of wireless transmission;

Whereas, finally the name of antenna is applied to a device assuming various forms, but ordinarily composed of a long metallic wire erected in space, a condenser, a transmitter or receiver of waves, *i.e.*, a capacity.

## Part Second—Examination of Various Marconi Patents

Whereas the Marconi device, patented in 1896, consists of a source of energy; one single electric circuit the spark producer, the self-induction and the antenna, which latter readily yields its energy to the ether in the form of oscillations and constitutes the capacity which with the self-induction provides the two factors, the product of which determines the periods of oscillation; whereas a second receiving circuit also contained the self-induction which, multiplied by the capacity of the condenser, with suitable adjustment gave the same product as that obtained by the same elements in the first circuit; and whereas this result precisely constituted the tuning of the two circuits in consequence of syntonization, ensuring the ready reception by the second circuit of the waves transmitted by the first; whereas, finally, the receiving circuit was provided with the improved Branly coherer in connection with a mechanical device which decohered the filings by a series of small and rapid taps;

Whereas this patent secured practical results and permitted of the establishment of wireless telegraphic stations, placing points several kilometres distant from each other in communication, but it was not able to escape from a law of which Lodge had spoken in his celebrated lecture in 1894, and which he expressed thus:

Whereas this double drawback existed in the Marconi arrangement; [fol. 2271] whereas as a matter of fact the transmitter through the very fact of being a good radiator was incapable of giving prolonged series of waves, and that the receiver by readily absorbing the waves was on that very account powerless to accumulate the effect of prolonged series, which condition, as we have seen, was indispensable for the proper utilisation of resonance;

Whereas under these circumstances Lodge applied for the patent 11575 of 10th May, 1897, taking up the general ground which Marconi had so well occupied, but remedying the drawbacks which have just been summarised by means of a compromise; whereas, indeed, not being able to abrogate the law he had promulgated he got over the difficulty by increasing the persistency of the oscillations in his radiator at the expense of its radiating qualities and increasing the possibility of his receiver accumulating the

effect of the waves striking the same at the expense of the absorption qualities; whereas the practical means was from the point of view of syntonization to introduce into the open circuit like that of Marconi an inductance producing a longer series of waves without greatly modifying their amplitude, and from the point of view of the increase of electric energy introducing two surfaces forming capacities, and having such a shape that the tendency of the circuit to lose its charge by brush discharge was reduced to a minimum whilst the amperage and the voltage of the oscillations was increased;

Whereas apart from this improvement upon the Marconi arrangement, that of Lodge was a reproduction of the same, whereas shortly after in the same year he took out a second patent number 29565, relating to inductive telegraphy, which is however interesting in view of the primary and the secondary of the system being provided with adjustable devices, permitting a precise syntonization and are tuned to the same frequency so that the secondary, which like the primary is a closed circuit, can act by the accumulation of the effects received by the application of the principle of resonance, which accomplishes selectivity;

Whereas there is no occasion to deal with Thomson's patent No. 525, taken out in 1898, relating to induction telegraphy, nor with Lodge's second patent, from which it does not very materially differ; these two patents, which are capable of furnishing interesting ideas, are without any direct bearing upon telegraphy by means of Hertzian waves, which was alone contemplated by the Marconi patents;

Whereas in the same year 1898 the latter took out a second patent under the number 12326;

Whereas the invention consists of an improved receiver in which the antenna is connected to earth through a primary, of which the secondary comprises the coherer, which raises the voltage so that the coherer may be more certainly affected by the signals received;

Whereas Marconi gives minute details as to the construction of these transformers which are without any iron core, [Vol. 2272] according to the type adopted by Tesla, to raise the voltage of high frequency alternating currents.

Whereas he took out two further patents also relating to the form of the receiver just referred to under the numbers 6982 and 25186 of 1899;

Whereas without for the present dealing with the Braun patent taken out under number 1682 of the same year, we can at last approach the fundamental patent applied for by Marconi on 3rd November, 1900, and granted on 1st February, 1901, "for improvements in wireless telegraphy."

Whereas this patent is thus worded:

Letters Patent No. 305,060. Improvements in Wireless Telegraphy by the "Marconi Wireless Telegraph Company, Limited."

"The object of this invention is not only to increase the efficiency of the apparatus hitherto employed, but also to so control the action as to cause intelligible communications to be established with one or more stations out of a group of several receiving stations.

In the patent No. 261612, a transmitter is described which consists of an induction coil, one terminal of the secondary circuit being connected to a metal sphere connected to earth and the other to a similar sphere connected to an insulated conductor which generally takes the form of a more or less vertical wire which may or may not terminate in a metal body of extended surface, giving it increased electrical capacity.

According to the present invention the vertical wire is connected to earth through the secondary winding of a transformer suitable for the transformation of very rapidly alternating electric currents, and the primary of this transformer is connected to the spheres or terminals of the sparking appliance.

A condenser of suitable capacity is introduced in series with the primary or each end of the primary may be connected to one of the plates of two condensers of suitable capacity, the other plates of which are connected to the sparking appliance.

This device enables much more energy to be imparted to the radiator than heretofore, the approximately closed circuit of the primary being a good conserver and the open circuit of the secondary a good radiator of wave energy.

The arrangement works as follows:—

On pressing the key and actuating the induction coil (in order to produce a signal) the condenser in circuit with the transformer is charged and discharges through the spark gap. If the capacity, the inductance, and the resistance of

the circuit are of suitable values, the discharge is oscillatory, with the result that alternating currents of high frequency pass through the primary of the transformer, and induce [fol. 2273] similar oscillations in its secondary, these oscillations being communicated to the vertical and elevated conductor.

The circuit of this conductor should be suitably attuned for this purpose.

The effect of these oscillations in the elevated conductor is to inductively affect similar distant conductors if the self-induction and capacity of the said conductors is of a suitable value or values.

At the receiving end a receiver is employed capable of being actuated by electrical oscillations of high frequency, such as those described in the Specification No. 283521.

The four circuits, namely, those including the primary and the secondary of the transformer in the transmitter, should be so adjusted as to make the product of the self-induction multiplied by the capacity the same in each case, *i.e.*, that their electric time period is the same, but they may also be harmonics of each other.

In employing this invention to localise the transmission of intelligence to one only out of several receiving stations the time period of the circuits at each of these stations is so arranged as to be different from those of the other receiving stations. If the time period of the circuits of the transmitting station are varied until they are in resonance with those of one of the receiving stations, that one alone out of all the number of receiving stations will respond, provided that the distance between the transmitter and receiver is not too small.

The adjustment of the self-induction and capacity of the circuits can be made in any convenient manner; those that are to be preferred are set forth in the following description:

Figures 1 and 2 are diagrams of the transmitter and of the receiver respectively, whilst Figure 3 shows a side view and Figure 4 an edge view of a transformer used at the transmitting station, and Figures 5 and 6 show various induction coils used at the receiving station.

A is a battery, B a Morse key, C a Ruhmkorff coil, the primary of which is in circuit with the battery, whilst the terminals of the secondary are connected to the primary D of a transformer, one of the connections being through a

condenser E or there may be a condenser in both of the connections.

The secondary D of the transformer is connected to an aerial conductor A which may have at its top a metallic cylinder F and to earth there is a capacity E. Between the secondary and the aerial conductor or it might be between the secondary and earth is sometimes inserted an inductance coil having numerous coils and the connection is such that a greater or less number of turns of the coil can be put in circuit, the proper number to use being ascertained by experiment.

The receiver (Figure 2) consists of an aerial conductor A which may have a cylinder F at its top connected through an inductance coil  $g^1$  similar to G and through the primary [fol. 2274]  $j^1$  of an induction coil to earth or a capacity E; a small condenser H may be inserted in parallel with the primary  $J^1$ .

The secondary  $J^2$  of the induction coil is divided in the middle and has its inner ends connected to the plates of a condenser  $J^3$ , while its outer ends are connected it may be through inductance coil  $G^2$  similar to G to a coherer T; a condenser  $H^1$  may be inserted in parallel with the coherer.

The local circuit containing a battery cell B and relay or telegraph instrument R is connected through choking coils  $C^1$   $C^2$  to the plates  $J^3$  of the condenser.

The condensers H  $H^1$  are preferably in the form of two metallic tubes separated by a dielectric and sliding telescopically on each other, as in this way their capacity can readily be varied to tune the circuits.

Whereas this abstract and highly scientific wording requires comment;

Whereas the invention, according to the happy wording of Mr. Seligmann, consists of the following: Since one single circuit in the initial arrangement of 1896 cannot be simultaneously a good radiator and a good oscillator, both for transmission and receiving, let us place two at each station combined, that is four; at the transmitting station a first highly closed circuit, which is very compact, containing an electric condenser, will be entrusted with the oscillation work, and then, through the medium of the transformer, will be placed in communication with a second circuit, that of the antenna, that of radiation, which is widely open and consequently excellent for its purpose. At the receiving station there are likewise two circuits: The

first, being a good absorber of electricity, will capture the waves by means of a transformer and will set in action another circuit suitable for properly preserving the electricity which will receive the Branly, the detector, the wave revealer;

Whereas this first result of the invention of the four currents is of supreme import, since it resolves in a very happy and simple manner the difficulty laid down by Lodge as insoluble, which, however, had already been partially overcome by him, as we have seen above;

Whereas the patent contains another equally important conquest from the point of view of the essential principle of resonance, the definition of which must again be borrowed from Me. Seligmann, who expresses it as follows: The four circuits must be tuned together, that is to say, they will all four have the same period, and in each of the four circuits the product of the self-induction by the capacity will be the same, but with varying factors of multiplication, so that each of the four circuits may be suited to its own particular function. The four tuned circuits will therefore be all four in resonance with one another; there will be synchronization between the transmitter and the receiver, synchronization between the primary and the secondary circuit on each side, and from this synchronization between the four circuits there will result a selectivity, that is to say, the receiving station will only be able to receive signals from the station or stations with which it is in tune;

Whereas this result is considerable, for it permits of the principle of secrecy in communications by agreements between correspondents having adopted the special "frequency" for their communications;

Whereas it was this result that permitted certain important applications to be made, such as those of the Berlin Conference, which imposed upon commercial messages wave lengths of 600 to 300 metres, whilst it is evident that other wave lengths will be adopted for diplomatic or military communications, which will be equivalent to a cryptographic cypher;

Whereas such was evidently (as was also affirmed by Mr. Justice Parker in his elaborate enquiry before the High Court of Justice in London, which terminated by the judgment of 21st February, 1911, in favour of the Marconi patent) the thought of the inventor, in spite of certain defi-

ciencies in the wording of the patent specification, which does not in express terms set forth the object aimed at by this syntonization to be accomplished between the circuits of the transmitter and those of the receiver; but whereas this object is sufficiently evident to the specialists, more especially as the inventor really explains how the selectivity is obtained; whereas all the foregoing is impliedly comprised in the first paragraph of the patent specification; whereas such is likewise the case with respect to the necessity of syntonizing the two circuits of the receiver, which fact is necessarily deduced from the requirements and results of the device described;

Whereas to conclude as regards the synchronization of the patent, lines 23 to 28 on page 2 of the specification should be noted, which comment upon the adjusting processes, and lines 78 to 85 on the same page, which summarily describe the actual process of regulating, viz., of the condensers, preferably in the form of two metallic tubes separated by a dielectric, and fitting telescopically within each other, so as to permit of readily varying their capacity in order to tune it with the circuits;

Whereas that is synchronization by adjustment or practically by rule of thumb, whereas this synchronization might result (which would be more scientific but less adaptable) from the very construction of the appliances, their characteristics, the length of antenna, the number of turns of the induction coils, and the capacities of the condensers being calculated so that *a priori* the period of the transmitter and that of the receiver are the same at the various stations and consequently give the same result everywhere, which precisely constitutes syntonization and hence the working of the apparatus;

Whereas there is no occasion to follow the specification as regards the minute details given as to the transformers, nor as regards the study of the very interesting synoptic table at the end of page 3 and the beginning of page 4, and which constitutes the experimental table for six tunings [fol. 2276] of the adjustments of each group; whereas thus the table of the transmitting station places opposite the six tunings numbered from 1 to 6 the elements of the aerial conductor, the number of the transformer, the nature of the inductance, the capacity in microfarads, finally the length of the spark in millimetres; whereas on the other hand the table of the receiving station places opposite each of the

six tunings the number of the induction coil, the capacity in microfarads and the inductance;

Whereas the last point to be examined is what is called loose or close connection or coupling:

Whereas scientists, and particularly the specialists who gave evidence in fact at the hearing before Mr. Justice Parker, recognise that the cumulative effect to which oscillations produced in a circuit may give rise in another circuit syntonized with the first one depends upon the manner in which the two circuits are connected, and that in order to obtain the greatest possible cumulative effect the circuits must be what is termed loosely coupled, because the cumulative effect of the primary on the secondary, which is syntonized with it, decreases in proportion as the coupling is closer;

Whereas doubtless this principle is not expressly stated in the 1900 patent, which, however, does not in any way impair its value, the same resulting from a harmonious, logical and rational general theory, that is fruitful in results, precisely because it constitutes complete and new invention, and whereas indeed nothing compels the inventor to use a formal wording, but he is free as to the manner in which he sets out his description and is entitled to all the profits thereof, provided his ideas are really and sufficiently expressed; and that therefore, although no mention is made in the letters patent of the condition termed loose coupling, which is one of the important features of the invention, it is wholly included in the invention for the sufficient reason that no expert can read and consider the patent without finding in the same evidence in support of the claim to loose coupling, and this as far back as 1900; that indeed such an expert on reading a passage in which it is explained how it is possible to obtain in a circuit a cumulative effect by means of oscillations obtained in another in a second circuit syntonized with the first circuit, would have understood that it was a necessary condition to provide a loose coupling of these two circuits inasmuch as the inventor wishes to obtain selectivity which necessitates the employment of a series of waves of almost constant amplitude, which cannot be obtained by means of close coupling, that is to say, in which the proportion of penetration of the lines of force of the primary into the secondary is 30 per cent. and over;

Whereas under these conditions the Marconi patent, both from the practical point of view and that of applied theory, does seem to have been the first to accomplish a new and very important industrial result, borrowing from what he himself and others had already found during half a century [fol. 2277] of research, carried on at first in purely speculative science without the least thought of the future practical value, and then on industrial lines foreshadowed by the combined efforts of men of great intelligence, thus little by little lifting the veil from the, as yet, unknown, and arriving at the Marconi patent of 1900, and whereas this patent typifies a wonderful conquest to which the young man of science puts a finishing touch by his unrelenting perseverance, but which nevertheless will doubtless only be the landmark of a considerable advance in the development of that new science which puts at the service of man the mysterious Hertzian waves, but which will be followed by other advances, the final result of which will be the elucidation and putting into use of new mysteries. And whereas this law of continual advance has already produced the Fessenden System allowing communication at 300 kilometres (1907), that of Forest, in which the arc heated by means of alcohol reaches to 50 kilometres; that of Poulsen (1908), in which communication is carried over a distance of 270 kilometres; that of the Telefunken Company, covering 75 kilometres with twelve arcs in series in the arc (1906-1907); that of Rhumer, allowing telephonic communication to be carried on over a distance of 50 kilometers by means of a high tension arc and a thermo-electric detector; that of the naval officers Colin, Jeance and Mercier, allowing communication to be carried on over a distance of 200 kilometres (1908); that of Majorana, transmitting the human voice to a distance of 420 kilometers (November, 1908), better than with the ordinary telephone, with 60 metre antennae and with oscillations produced by means of a Poulsen arc and a receiver consisting of a detector with crystals;

But whereas, for the present, on this battle-field of our invasion of the unknown, the Marconi patent is based upon claims stated as follows: \* (1) "a transmitter for electric wave telegraphy consisting of a spark producer, having its

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\* Extract from French patent No. 305,060, Page 4, Lines 18 to 76.

terminals connected through a condenser with one circuit of a transformer, the other circuit being connected to a conductor, and to a capacity (2) a transmitter for electric wave telegraphy, the combination of a transformer, one of the circuits of which is a persistent oscillator and the other a good radiator, and devices for creating oscillations in the oscillator (3) a transmitter for electric wave telegraphy, consisting of a spark producer, having its terminals connected through a condenser with one circuit of a transformer, the other circuit being connected to an earth conductor, the time period of the electric oscillations in the two circuits being the same or harmonies of each other (4) a transmitter for electric wave telegraphy, the combination of a transformer, one of the circuits of which is a persistent oscillator, and the other a good radiator, the time period of the electric oscillations in the two circuits being the same or harmonies of each other, and devices for creating oscillations in the oscillator (5) a system of electric wave telegraphy, in which both the transmitter and the receiver contain a transformer, the time period of the electric oscillations in the four circuits of the two transformers being the same or harmonies of each other (6) a system of electric wave telegraphy, in which both the transmitter and the receiver contain a transformer, one circuit of which is a persistent oscillator and the other a good radiator or absorber of electric oscillations, all four circuits having the same time period or being harmonies of each other (7) a transformer for electric wave telegraphy, the combination of a pair of terminals, or devices for producing sparks between the terminals; of a connection transformer between one of the turns of the transformer and the terminals, of a condenser in one of the connections, of a conductor, of a capacity and connections between the other turn of the transformer and the conductor and the capacity (8) apparatus for wireless telegraphy substantially as described and illustrated."

### Part Third: Anticipations

Whereas the opponents of Marconi recognise that the latter had first the honour of obtaining practical results from the discovery of Branly in establishing telegraphic communication by means of Hertzian waves in the historical experiment between Dover and Calais, but whereas they

allege that Marconi only employed what had been discovered before him by Popoff, Tesla, Lodge, Braun and Duguet;

Whereas all these independent endeavours tending however towards the same end are put forward as anticipations rendering the patent set up null and void by reason of want of novelty.

But whereas Marconi does not allege that he discovered at one stroke everything that constitutes his system; and that on the contrary he is modest enough to introduce his patent under the heading: "Improvements in wireless telegraphy," and whereas according to the French law a patent can be obtained for any combination bringing about by means of previously known processes a new industrial result, which is the only ambition of Marconi:

Whereas we are not concerned to discover whether the elements which constitute the patent of 1900 were or were not known, but whether the result obtained by Marconi was new, either in respect of a total or partial new arrangement or of an industrial result constituting an advance on the previous position:

Whereas, as has already been said, the four syntonised currents in particular constituted a new arrangement, Marconi being the first who succeeded in operating wireless telegraphy in a practical manner over long distances, thus securing his position of eminence in this branch of applied science.

Whereas, moreover, the anticipations which are alleged against the patent of 1900 would have been victorious only if they had established that this patent was an impudent [fol. 2279] plagiarism and not the synthetical result of interesting efforts but powerless to attain the same result:

Whereas these efforts deserve to be brought into prominence, since they were made by those scientists who following one another have the honour of having contributed to the success of a great discovery, some by purely speculative researches, as for instance, Henri in 1839, Maxwell, Hertz, Heaviside, Poyntwig and others, afterwards on the lines of practical applications, such as Branly, Sarrazin, Delarive, Poincaré, Bjerkness and Blondlot, modifying the formula of Hertz in order to amalgamate it with that of Thomson, Gutton and Turpin by means of his studies on interference fields and propagation in dielectrics; Righi

by means of his researches on reflection and refraction; Lebedey from the point of view of optics with his electromagnetic waves; Blondel with his excellent calculations, and very many others;

Whereas Popoff, whose name has been mentioned as an anticipation, which fact has not been borne out either in the arguments or in the pleadings, had made considerable advance by his publications and his communications to Russian scientific societies, showing by his experiments that he could enable the Navy to transmit and receive signals over long distances; and whereas, starting on studies in atmospheric electricity, he had in theory reached wireless telegraphy and even the idea of tuning, but whereas he had not been able to set foot on the territory of actual practice, because he was unable to generate undulations powerful enough to produce the waves; just as in the case of Tesla he had not discovered the method of receiving them;

Whereas the foregoing is interesting because these details are supplied by Dueretet whose alleged anticipation, which will be discussed later, is swept away in advance by the fact that speaking with reference to Popoff on the matter of tuning (which forms the basis of the Marconi patent) as a preface to his own apparatus, he had no thought of using for himself this essential principle, from which it follows that he was, through his own fault, taking the opposite lines to the Marconi system;

Whereas, moreover, neither in the argument nor the submissions was any weight attached to the works of Popoff, which, while very interesting, have no influence on the Marconi patents in which other principles and entirely new mechanisms have been used;

Whereas under these circumstances it behooves us first to consider in their chronological order the anticipations referred to in the pleadings and in the submissions; that is to say, the Lodge patent of 1897, the Dueretet apparatus described in 1898, the second Marconi patent, which became public property on failure to pay the fees in 1910, the Braun patent number 1862 of 1899 and the Tesla patents, the first taken out in France in 1897; the other taken out in America in 1910; as to the Lodge patent (No. 11575 of 1897); [fol. 2280] Whereas due homage has been above paid to this learned Englishman who was the first to define exactly the real and apparently insurmountable difficulty, viz., that the strong radiation of the waves was incompatible with

the generation of persistent oscillations; and also to the ingenuity with which he partially overcame the before-mentioned obstacle by increasing the persistence of the oscillations in the radiator at the expense of its radiating qualities, and in the opposite direction by increasing the possibility of his receiver accumulating the effects of the waves that strike it at the expense of the absorbing qualities of that receiver:

But whereas the patent went further, inasmuch as it is taken out like that of Marconi under the modest heading of "Improvements in syntonised telegraphy ~~without~~ line wires," which is indeed, as in the case of Marconi, an evidence of considerable effect in the same direction pointed out by the 1896 patent:

Whereas Lodge, in a description which Mr. Taillefer himself considers too long to be examined in all its details, demonstrated clearly that he came very near to the patent set up, but as a matter of fact fell just short of the last stage of the final invention capable of industrial application; and whereas, in fact, he faces the problem of the use of the resonance principle in a system of wireless telegraphy, insisting not only on the efficiency it should have over long distances, but also on the fact that in making use of this principle it ought to be possible at one or several receiving stations, provided with syntonised receivers, to receive messages, whilst other stations provided with receivers syntonized for a different frequency or wave length would be in no way affected, which, in practice, meant that it would be possible to secure selectivity under the conditions inseparable from this new mode of communication:

But whereas it is necessary to quote literally at least the characteristic parts of the patent, as follows:

The method of intercommunication consists, according to my invention, in utilising certain processes and apparatus for the purpose of producing and detecting a sufficiently prolonged series of rapid electric oscillations and in so arranging them that the excitation of a particular frequency of oscillation at the sending station may cause a telegraphic instrument to respond at a distant station, by reason of being associated, through a relay or otherwise, with a subsidiary circuit capable of electric oscillations of that same particular frequency, or of some multiple or sub-multiple of that frequency. Another distant station will similarly

be made to receive messages by exciting at the sending stations alternations of a different frequency, and so on; and thus individual messages can be transmitted to individual stations without disturbing the receiving appliances at other stations which are tuned or syntonised to a different [fol. 2281] frequency. Each station will usually be provided with both sending and receiving apparatus. • • • •

As charged surfaces or capacity areas, spheres or square plates or any other metal surfaces may be employed, but I prefer, for the purpose of combining low resistance with great electrostatic capacity, cones or triangles, or other such diverging surfaces, with the vertices adjoining and their larger areas spreading out into space, or else a single insulated surface may be used in conjunction with the earth, or the conductors embedded in the earth constituting the other oppositely charged surface.

Radiation from an oscillator consisting of a pair of capacity areas is greater in the equatorial than in the axial direction, and accordingly, when sending in all directions is desired, it is well to arrange the axis of the emitter vertically. Moreover, radiation polarised in a horizontal plane, that is, with its electric oscillations vertical, is less likely to be absorbed during its passage over partially conducting earth or water. A pair of insulated capacity areas arranged for long distance signalling is shown on the left-hand side of Figure V.

Another plan, and one well adapted to secure accurate tuning, is to arrange some of the whole of a syntonizing coil so that its parts may be made to approach or recede from one another. This one I call an adjustable coil, the others I call replaceable or interchangeable coils.

A receiver or resonator consists of a similar pair of capacity areas connected by a similarly shaped conductor to a self-inductance coil, the whole constituting an absorber arranged so as to have precisely the same natural frequency of electrical vibration as the radiator in use at the corresponding emitting station.

Whereas Mr. Justice Parker, after having studied this patent, basing his argument on Figure XIV., justly calls attention to the fact that, according to Lodge, the open circuit of his receiving aerial is connected through a transformer with a closed circuit containing the coherer, in order to allow the electric oscillations to develop more freely in his receiving aerial without any disturbance from

attached wires; whereas the secondary circuit as it is represented is not syntonized and cannot be syntonised with the circuit of the antenna; hence it follows as the English Judge very well says in his own fashion that the 1900 invention of Marconi was not so obvious that the patent which protects it can be said to be deprived of its subject matter; and whereas he confirms this finding when he says:

In introducing two circuits at the receiving end, Lodge does not see that if only he had utilised the principle of [fol. 2282] resonance as between those two circuits the problem would have been solved, at any rate at the receiving end, and really the problem at the transmitting end is the same problem as the one requiring solution at the receiving end, but from the reverse point of view. The common knowledge of the art was, as far as material for the present purpose, the same when Lodge prepared his 1897 specification as when Marconi prepared his specification. How then can I treat as obvious at the latter date what so able a man as Lodge entirely failed to see in 1897.

Whereas Mr. Seligmann has clearly expressed this opinion, making it more striking when he says that Lodge has no idea whatever of the four circuits of Marconi; he uses a high capacity radiator, he endeavours to excite his radiator, and for this purpose he makes use of several devices for excitation, in one of which there is something vaguely resembling two circuits, but which is nothing of the sort; the purpose of the first circuit is to prevent communication between the source of energy and the excitation circuit; there is no common magnetic field between one circuit and the other, and both oscillation and radiation are entirely performed in the single circuit: "With the receiver we shall come nearer to, without however reaching the Marconi receiver, two circuits, with a common magnetic field, these circuits being capable of being put into communication by induction, which is a resemblance, but differing in that the purpose of this arrangement is to provide a screen, and not the cumulative effect of the Marconi device, to prevent the reaction of the coherer wires on the work of absorption on the two capacity surfaces, which constitute the antenna . . . the result sought after being that the resonator, the antenna, may vibrate without disturbing the attached wires, that is to say, those of the

coherer \* \* \* far from endeavouring to unite them, it is sought to separate the functions of the antenna and that of the coherer; the two currents therefore have a common magnetic field \* \* \*. At this stage, Lodge is, so far as the receiver is concerned, very near to solving the difficulty but he did not understand that in using between the two circuits, the principle of resonance, the difficulty was solved, at least with regard to receiving. It has not been stated that in the two circuits the product of self-induction by capacity is the same in both, neither can they be adjusted; on these two circuits there likewise is no possibility of modifying them to enable them to be tuned one with the other; there are certainly two circuits, but not two circuits that can be tuned, and as it is not possible to regulate the two circuits, it is impossible to bring them into resonance."

Whereas it was justly held by the English Court on this point that the Marconi patent was valid:

Whereas it is true that the opposite side take consideration [fol. 2283] able pains to show that Mr. Justice Parker contradicted himself in afterwards granting an extension of time to the Lodge patent, but it is sufficient to read this latter judgment in order to be convinced that this apparent contradiction is explained by the modifications introduced into the original wording of the patent and as a kind of indirect remuneration for the efforts of Lodge although overridden by Marconi.

With regard to the researches of Ducretet:

Whereas the latter thus explains his apparatus in his communication on Hertzian wireless telegraphy in the issue of December, 1898, of the "Bulletin de la Société d'Encouragement pour l'Industrie Française" (p. 1632 and following):

As in the case of telegraphic apparatus the appliance consists of a transmitter and a receiver.

The principal part of the transmitter is a Ruhmkorf induction coil, which is very powerful if it is intended to operate a long distance. The model I have designed is quite portable and strong. The coil is entirely contained in a closed box filled with our insulating mixture. The condenser is fixed in the base. The sparks are hot and copious.

In the coarse wire inductor circuit there is either a Neef's magnetic hammer break with an immediate starter, or an interruptor with a continuous action motor, or an independent interruptor with cams and contacts immersed in an insulating liquid.

The independent interruptor with the continuous action motor is suitable for high power coils, and its working leaves nothing to be desired in regularity and speed.

A special key worked by hand produces long or short intermittent currents in the inductor circuit of the induction coil.

The current is generally supplied by a battery of accumulators or by a dynamo. It is this electrical energy of a certain intensity but of an electro-motive power of only a few volts which is transformed, in the neighbouring circuit of fine and long wire, well insulated from the inductor circuits, into a high electro-motive force exceeding 200,000 volts for a coil giving sparks 26 centimetres in length.

This very high tension allows of sparks being obtained which are discharged between the spark balls of the transmitting oscillator and thereby electric waves are projected into space.

It is unnecessary to point out that this transformation of electric energy of a high potential as set up by this induction coil is produced with a primary electric energy not exceeding 70 watts or about 1/10 h. p. In certain cases it is desirable to earth one of the terminals of the inductor wire at the same time as one of the terminals of the induced wire.

The oscillator can be constructed according to the data of Professor Rhigi; my design permits several combinations of sparks to be obtained and also allows of variations in [fol. 2284] their length. The trough R. receives the insulating liquid and the peep-hole allows the spark which is formed inside between the spheres to be observed.

The figure fully illustrates the transmitter which has just been described.

It comprises:

Induction coil,

Interruptor with independent motor,

Hand key,

Spark oscillator.

The system consists of two or three balls as used by Messrs. Lodge and Bose.

The outer insulating columns receive the discharging balls, the spark gap being adjustable.

The central column bears the intermediate ball which is fixed. The parts of these balls between which the sparks pass have been made rust-proof.

A special hardwood box with a lid encloses the whole; the sparks are hidden by means of plates. The complete apparatus being free from contact with the ball rods at any point cannot interfere with the discharge of the powerful Ruhmkorf coils.

This oscillator works without any insulating liquid. The wires of the induced circuit of the induction coil reach to the discharge balls of the oscillator. The connection to earth, the connection with the radiating wire of the mast.

The receiver illustrated in Figure III. is Ducretet's portable model, it is derived from that of Popoff.

Br is my adjustable model of Me. Branly radio-conductor, with ivory tube. The filings are placed between the two variable pressure metallic conductors. The action of the outer air in the filings is avoided, as well as its renewal. Through the terminals T and L the electrodes of this tube of filings are connected, one to earth and the other to the collecting conductor wire which with the radiating wire forms the Hertzian line in space:

F.—Automatic tapper arranged after the manner of Popoff. It is provided with the adjustable parts R.

R.—Very sensitive polarized relay; it closes the circuit of the tube of filings Br and puts in action the local current, as has been said, for the purpose of operating the tapper and the registering apparatus.

In 1893, with the collaboration of Mr. Maréchal, we had pointed out the use of moving-coil galvanometers, in making use of the ballistic effect of the moving coil to form very sensitive telegraphic relays. They can be made of any dimensions.

Electric resistance without self-induction.

I am successfully using liquid resistance which my volt-[fol. 2285] ametric rheotome with aluminum rods allows me to obtain. These auxiliary resistances serve for the purpose of avoiding the effects of the induction current at breaking. The one on the left is not indispensable in every case.

The battery elements which are necessary for working this portable receiver are inside the box.

E and S are the interruptors of the current of those batteries.

In many cases this very portable apparatus is sufficient for reading the sounds of the Hertzian telegraphic signals. In order to register them it is sufficient to connect the two terminals R by a double conductor of any length to the terminals R of the portable automatic Morse, to which I shall refer again. An ordinary registering Morse apparatus arranged for that purpose can be employed; but we shall see later the acknowledged superiority of an automatic apparatus.

To register the electric waves produced by atmospherical disturbances it is sufficient to connect the terminals R (Figure 9) to those of a meteorological registering apparatus; this will be described in a special chapter.

Figure 10 shows all the parts of mechanism just described, combined at one station. The auxiliary resistances are not shown. This apparatus was the subject of a communication to the Académie des Sciences on the 2nd of May, 1898.

For military or exploration purposes the whole plant, viz., transmitters and receivers with masts and necessary equipment and posts to be sunk in the ground, can be placed inside telegraph or post office vans. High speed motor vans would be very convenient.

For flying Hertzian wave telegraphy the portable station shown on the figure will suffice for reading the sounds; it can always be connected to the portable registering apparatus.

Ducrotet's automatic registering apparatus. As I have always stated, this registering apparatus works automatically; it does away with the telegraph operator for the immediate reception of the signals. In the case of Hertzian wireless telegraphy, this device is of great importance. On account of the extreme sensitiveness of the Branly radio-conductor the receiver can register all electric waves capable of influencing the tube of filings, even if they are of atmospheric origin. It therefore would be necessary to keep a telegraph operator permanently at the apparatus in order to unwind the paper at each call and stop it when the electric waves ceased to act.

By making the receiver automatic I do away with the necessity for the actual presence of the operator for receiving the electric waves and signals.

Without any assistance, the receiver automatically unwinds the paper as soon as a wave acts upon it, and in the [fol. 2286] same manner stops as soon as the waves cease. A blank space separates each message or each record of atmospherical electric waves.

Whereas the quotation is not too long, inasmuch as this alone would induce any person who had but a superficial knowledge of the Marconi theory to ask himself how it could ever have been thought possible to discover in the Dueretet apparatus, consisting of a single circuit and in which the transmitting antenna is directly bound up with the spark producer, the same apparatus as that of Marconi with its two circuits syntonized one with the other, and influenced by a transformer and a condenser:

Whereas, moreover, as has been seen above, Dueretet began his description by a sketch of the system of Popoff in which he stated that this system was in part based upon tuning or, speaking precisely, on syntonization, and that he had not thought of making use of this essential element of the Marconi patent in his own apparatus, from which proceeds the most categorical denial of any possible anticipation.

Whereas, however, Dueretet was able to exchange messages between the Eiffel Tower and the Panthéon, just as Popoff had likewise sent signals to a distance, which Marconi does not think of contesting, for the very simple reason that he claims as his, not the principle of wireless telegraphy, but the improvements on the processes in use before he took out his patent.

With regard to the Marconi anticipation of 1898:

Whereas in this patent, which lapsed to the public in 1910 on failure to pay the fee and was then indeed without any interest, Marconi puts two circuits in his receiver, just as Lodge moreover did, not for the purpose of syntonising the director circuit and the receiving antenna circuit but simply to employ the transformer to increase the voltage at the terminals of the detector, and whereas it was for this reason that he gives 200 turns to the primary of the transformer, which he necessarily employs and 800 turns to his secondary, but whereas he does not point out any more than Lodge that the two circuits must be tuned, and does

not give any formula for this tuning by means of characteristic numbers or any process of regulation by tentative methods, as it seems natural he would have done if at that time the necessity for this syntonisation had been obvious.

With regard to the Braun Patent:

Whereas there exist three Braun patents: In France that of the 4th January, 1899; in England that of the 26th January of the same year, and finally that of the 7th July, 1900, granted in Germany after examination by the Patent Office:

Whereas this patent endeavors to solve numerous difficulties and commences the description by dividing the electric waves into three classes: (1) Those of low frequency obtained by ordinary alternating currents mechanically produced; (2) those of much higher frequency, produced by a Leyden jar discharge with or without inductance coils in circuit, which no doubt means with or without the introduction into the circuit of inductance coils in order to reduce the frequency, and consequently to increase the wave length; (3) those of very high frequency produced by Hertz, not by means of Leyden jars and special inductance coils, but by means of ordinary conductors, the capacity and inductance of which are comparatively weak; and whereas Braun goes on to say that in wireless telegraphy the inventors up to that time had concentrated their attention upon the third group of oscillations which he calls Hertzian waves their only object being to increase their frequency; and whereas he afterwards mentions the practical difficulty resulting from the use of very high frequency waves, claiming that the object of his invention is to remove this difficulty by using electric oscillations belonging to the second group, *i.e.*, oscillations having a low frequency in comparison with the frequencies used up to that time, which suggests to Mr. Justice Parker the very judicious remark that the inventor was perfectly aware of what had been done by Marconi, as the latter was already using and Lodge had proposed to employ oscillations belonging to the second group of Braun;

Whereas Braun proceeds as follows: Another advantage, perhaps even of more importance in the use of slower oscillations, is that their potential and their amplitude and consequently the energy that is transmitted can more easily be increased. When Hertzian waves are employed there is a certain length of spark that cannot be exceeded when it

is desired to employ the circuit for the purpose of creating oscillations, otherwise the damping of the oscillations becomes too great, the tension of the system diminishing gradually, instead of doing so suddenly; the result is that the effective potential is limited, a disadvantage that does not occur, or that can easily be avoided, if slower oscillations are used;

Whereas it is rather difficult to discover the meaning of this sentence, which gave rise to important discussions in the English enquiry; and the most feasible meaning is that Braun has in view to increase the energy transmitted to the ether by means of the radiating circuit and that he considers that this result may be attained by increasing the potential and the amplitude of the electric oscillations in this circuit, and that he also considers that he can more easily increase this potential and this amplitude by making use of slower oscillations, pointing out, what is perfectly true, that if Hertzian waves are used the potential or voltage cannot exceed the voltage that can be borne by the spark producer without allowing the spark to pass;

Whereas he further points out that if in order to obtain a higher voltage one wishes to increase the length of the spark, it is soon found that the process cannot be continued inasmuch as according to Lord Kelvin's law there is a maximum resistance that cannot be exceeded if it is desired to [fol. 2288] produce oscillations; and that, in fact, an increase in the width of the spark gap results in an increase in the resistance of the circuit;

Whereas in this instance again the exact meaning of the description is not clear; and, indeed, what Braun says of the Hertzian waves is true whatever be the frequency of the oscillations;

Whereas Mr. Justice Parker in the following comments describes the position in a remarkable manner:—

In no case can you increase the length of the spark gap indefinitely without being pulled up by Kelvin's law. Braun may mean that you can get a greater allowable resistance if you use longer waves, that is, the product of the capacity multiplied by the inductance, but if the maximum allowable resistance is equal to the square root of four times the inductance divided by the capacity, its increase is therefore produced when the wave length (or the product of the capacity by the inductance) is increased, or by in-

creasing the inductance, or by increasing the capacity, that is the increase of the maximum allowable resistance does not directly depend upon the increase of the wave length, but upon the means adopted for increasing such wave length. Further, it is not clear on the evidence whether you could by increasing the wave length in any way obtain a higher potential in the oscillations resulting from the discharge of the condenser; the maximum potential is limited not only by the length of the spark gap but also by the tendency of the circuit to a brush discharge, and in other ways, and this renders the problem one of considerable complexity.

Whereas Braun goes on to state that he has discovered that the oscillations produced by the discharge of Leyden jars of ordinary dimensions in a circuit having a moderate inductance are quite suitable for the transmission of signals and that the experiments show likewise that for the same expenditure of energy in the transmitting circuit it is preferable to have recourse to slower oscillations, this formula is insufficient, which caused Mr. Justice Parker to say: "Here again it cannot be said that Braun clearly expresses what he means to say, unless he means to refer to the practical difficulty which he has already mentioned as inherent to the use of the Hertzian waves."

Whereas Braun further states that the Leyden jar or any other apparatus used for producing electric oscillations is connected to the spark producer of a Ruhmkorff coil or a Wimshurst influence machine and is provided with the well-known vertical wire used for transmitting the waves, which wire must preferably have a considerable length; he also states that at the receiving station the ordinary device may likewise be utilised in so far as the vertical wire receiving coherer, the local battery and the registering [fol. 2289] device are concerned, as in a Morse or any similar apparatus;

Whereas it is evident that in this quotation he refers to things which he considers as being in current use and not forming part of his invention, strictly speaking; and whereas here again, however, it is difficult to ascertain what are the matters he refers to; and whereas an electrical engineer doubtless might at first sight think that Braun is referring to the vertical antenna of Marconi and which at the time of the Braun patent was in fact of considerable length,

but that on further reflection, as Mr. Justice Parker says, an electrical engineer well versed in the subject might think or might be led to think that the point is dubious, as he would remember that Marconi was already making use of frequencies of the kind which Braun claimed as having employed for the first time, and he would therefore arrive at the conclusion that Braun was not aware of the Marconi antenna and simply meant a vertical wire of such very low inductance and very low capacity, that, if it had been employed alone, it might have led to the creation of very high frequency oscillations; moreover, even if this electrical engineer were to suppose that Braun meant to describe the apparatus usually employed by Marconi in both the transmitting and the receiving stations, he would probably arrive at the conclusion that Braun had no intention to synthesise, inasmuch as in the process to which he called attention he apparently diminished the frequency of the transmitting circuit without indicating the method of effecting a corresponding decrease in the frequency of the receiving circuit:

Whereas Braun concludes his description by saying that in order that his invention should be clearly understood, he has shown in the drawings annexed to his patent, and as an illustration, some arrangements of circuits used for transmitting signals by means of electric oscillations of the kind just described; that is to say, by means of oscillations belonging to his second group, but whereas his invention is not limited to the precise arrangements which he described, because these latter may be very considerably modified and low frequency electric oscillations suitable for transmitting signals according to his system may be generated in several other ways.

Whereas this obviously means that the principal object of his invention consists in the use of frequencies belonging to the second group, whatever may be the mode of generating the same, and not in a particular process for obtaining the frequencies; and whereas it will be necessary to hold that his first claim refers to the improvement in the process of transmitting messages by means of electricity without a conducting wire, an improvement which consists in making use of electric oscillations of comparatively low frequency, such as those which are produced by the discharge of a Leyden jar with or without an inductance coil in the circuit, substantially in the manner described in the specifica-

[fol. 2290] tien; and that the second claim refers to a combination of apparatus substantially in accordance with the specification;

Whereas in view of all the foregoing it is clear that the wording does not contain the least hint with regard to the problem which the Marconi patent of 1900 proposed to solve, and still less, even any indication of efforts being made towards the solution of such a problem, from which it follows that if the Marconi patent was anticipated by anything similar to be found in the Braun specification, such should be seen in the drawings of Braun; and whereas all these drawings are diagrammatic, and no details whatever are given, and if it wished to derive from them anything approaching Marconi's invention of 1900, it is impossible to arrive at that result except by introducing certain details of construction, and so gaining the end Marconi had in view.

Whereas drawing No. 1 illustrates the vertical wire or antenna connected to the inner coating of a Leyden jar, the inner and outer coatings of which are connected to spark balls, and the circuit also contains a small inductance coil; whereas drawing No. 3 illustrates the same device with this difference, that the two Leyden jars connected in series take the place of the single Leyden jar of the drawing; whereas drawings Nos. 2 and 4 correspond to drawings Nos. 1 and 3 respectively, with this difference, that in these drawings the inductance coil is represented as constituting the primary of a transformer; one of the terminals of the secondary of that transformer connected to the vertical wire or antenna, and the other, according to drawing No. 2, to the outer coating of the Leyden jar, or, according to drawing No. 4, to a capacity of any kind, which may be the earth;

Whereas, according to the wording, the function of that transformer is to increase the voltage, although this cannot be considered as explaining the method in which the inventor thought that the potential of his circuit could easily be raised by utilising oscillations of comparatively low frequency, inasmuch as this method is equally applicable to oscillations of any frequency whatever;

Whereas, indeed, in order to arrive at the result which the inventor wished to attain, the effect of that transformer would in a large measure depend upon the condition in which the two circuits might be, with regard to their more or less close coupling and also to their relative capacities.

the maximum voltage possible to be reached in the second increasing in proportion as the capacity of the circuit decreases; and whereas it results from the wording of the specification that Braun obviously understood the well-known vertical wire of which he spoke as having a very low capacity in comparison with that of the Leyden jar which he proposed to introduce in his transmitter, and it likewise results from this wording that he considered that the circuit of that Leyden jar should be the circuit fixing the value of the energy transmitted to space and the length [fol. 2291] of the electric waves; Braun, however, says nothing of the time period of the secondary circuit, although it may be probable that he thinks he can increase the potential of the oscillations in this circuit by means of a transmitter, apparently simply on account of the low capacity of this circuit; he must therefore have fancied that the time period of the primary would necessarily apply to the secondary, whatever might have been its natural time period, a result which in reality could not be obtained otherwise than by resorting to the closest possible coupling;

Whereas this conclusion is corroborated by drawings Nos. 1 and 3, in which, strictly speaking, there is only one circuit; and, if, as from a certain point of view is possible, these drawings are considered as illustrating devices containing two circuits, it will be seen that these circuits are as closely coupled as possible, although, however, in this case also the degree of coupling would depend upon details of construction, which are not given; just as, moreover, no details with regard to the syntonization of the two circuits are given;

Whereas, however, if it is true that anybody well acquainted with the Marconi invention of 1900 could easily adapt the device illustrated by drawings Nos. 2 and 4 in such a manner as to obtain the results indicated by Marconi, by introducing into these devices proper details of construction as well as the arrangements referring to syntonization, &c., it is certainly no less true that neither the drawings nor the specification of the Braun patent contain any suggestion either of the problem to be solved, or of any detail of construction which would enable one to obtain a solution, from which it follows that the patent in question cannot be considered as an anticipation of Marconi's patent, seeing that there can be found in it nothing characteristic of the latter

patent, *i. e.*, four circuits syntonized in pairs, and in two groups in their turn syntonized with each other.

Whereas this finding is confirmed by Mr. Justice Parker in this ironical but eloquent manner: "In my opinion any competent engineer would most probably have put Braun's specification altogether aside as being founded on a mistake as to the frequencies then in use and otherwise containing so many points of difficulty. He would have said, 'Marconi is already doing what Braun claims and it is useless pursuing the matter further.' Even if he had been struck with, and desired to test, the apparatus diagrammatically shown in the drawings, there would be no reason why he should work on drawings Nos. 2 and 4 rather than on those Nos. 1 and 3, unless his object was to get high voltage in the vertical wire. If he desired higher voltage he would, I think, have coupled his circuits as tightly as possible and rushed his current through. Even if he had thought of tuning he would have thought of it only in connection with securing a high voltage and not in connection with securing a cumulative action by the primary on the secondary so as to get a long train of waves."

[fol. 2292] Whereas the Defendants in the inspired language of Me. Taillefer vainly endeavour to demonstrate the anticipation of Braun's patent with regard to resonance, which is understood to be the principal point of the argument, and whereas he expresses his view in saying that Marconi had combined Braun's transmitter with the Marconi-Lodge receiver, and whereas consequently the combination of the patent was not new in 1900 (Shorthand Notes, page 65).

But whereas Braun's patent did not mention tuning; and whereas if he employed two circuits and one transmitter he did not employ two syntonized circuits; and whereas consequently Marconi, founding his 1900 system on the four circuits theory, did not steal from Lodge and Braun but brought out an entirely new device containing elements which neither Lodge nor Braun had contemplated in combination; and if Marconi had limited his efforts to this, his patent would be above criticism, since a patent may be obtained for any new industrial result obtained by the combination of means already known; and there can be no question as to the reality of the industrial result of Marconi's combination as the world is now encircled with what did not exist before;

Whereas it is appropriate to quote in support of this finding the following passage from Pouillet, who is so deeply regretted, but who has found such worthy successors:

"To combine for the first time elements which had hitherto remained separated is, in fact, to apply them in a new manner. It is, therefore, of little importance whether all the elements of a machine were even for time immemorial public property, provided the combination be new. It is, indeed, one of the most usual forms of new discoveries."

With regard to the Tesla's Patents:

Whereas it is on this alleged anticipation that the last and greatest effort of the Plaintiffs was finally centred, treating as of secondary importance the anticipations which have just been ruled out, and this would seem impliedly to recognise as reasonable the sudden resumption of the attack on a new ground and with new weapons:

Whereas the Defendants review in succession the 1896 patent and that of October 25th, 1897, the first of which describes a transformer in which the secondary is connected to the antenna, the circuits tuned in such a manner that, as Mr. Thillefer says, there should be the closest possible resonance for the oscillations created in the primary, which would constitute an anticipation of Braun and *a fortiori* of Marconi; and whereas this would appear from a "Manual of Wireless Telegraphy", published in 1900, and in which Murray writes the following:

It is a transmitter in which there are two flat coils. It is an antenna circuit comprising two flat coils; the circuit is connected to a source of electricity. . . . [fol. 2293] This source is generally a condenser laden to a high potential and discharged in rapid succession into the primary element. . . .

But when it will be desired to produce waves of very great length, an alternating dynamo of suitable construction may be used to supply the energy. . . .

The actual constant quantities of the coil constitute its time period. They are selected and adjusted in such a manner that the secondary system should be as far as possible in resonance with the oscillations created in this system by the primary.

In collecting the energy of these disturbances in any terrestrial region at a distance from their source for any purpose.

Whereas it is endeavoured to extract from this quotation a proof that the Tesla patent gave an exact description of Braun's transmitter, and pointed out that the actual constant quantities of the coils are adjusted and selected in such a manner that the secondary should be in the closest possible resonance with the oscillations communicated to this element by the primary:

Whereas the conclusion is drawn that there are in the transmitter two systems in resonance with each other; and whereas another quotation is given as follows:

In collecting the energy of these disturbances in any terrestrial region at a distance from their source for any purpose . . . and, more especially, in appreciable amounts, the most economical results will be generally secured by the employment of my receiving transformer.

This invention, forming part of my system of transmission of energy through the natural media, has been fully explained in the patents first cited here, but for the better understanding of the present description it is diagrammatically illustrated in Fig. 174. Its most essential part is a circuit  $E^1 C^1 D^1$ , which is connected and arranged similarly to the transmitting circuit  $E C D$ , and which is inductively linked with a secondary circuit  $A^1$ . The latter, it scarcely need be stated, may be wound with any desired number of turns, such as will be best suited for the operation of the device designated by  $M$ . The receiving transformer is closely attuned to the oscillations of the transmitting circuit, so that, irrespective of the length of the conductor, the points of maximum potential coincide with the elevated terminal  $D^1$ , under which conditions the greatest amount of wave energy may be collected, &c.

[fol. 2294] Whereas it is submitted from the foregoing that there is a complete similarity between Tesla's invention and that of the four syntonized circuits of Marconi;

But whereas this becomes more and more doubtful on a perusal of Tesla's French patent of the 25th October, 1897, granted under number 271641:

But whereas it is necessary to preface this perusal by the two patents of Tesla taken out in 1891 and 1896:

Whereas in Figure 1 of his first patent Tesla illustrates a transformer by means of which he proposed to raise the voltage of the oscillations created by the sudden discharge of a condenser for the purposes of illumination. The coup-

ling of the circuits is in consequence as close as possible; and no mention is made of syntonization, even admitting that in this case it would have been possible to syntonize;

Whereas in his second patent Tesla insists on the fact that he syntonizes his circuits with each other, but whilst on the one hand he gives some explanations on the syntonization of some circuits which could not in fact be syntonized with one another, he gives none with regard to the syntonization of his discharge circuit with his working circuit, the two circuits with regard to which any reference to syntonization would have been of specific importance.

Whereas this is all the more strange as in a lecture which he gave in 1893, Tesla showed a transformer, the secondary of which comprised an adjustable condenser used for the purpose of syntonizing the secondary with the primary. In this lecture he had discussed the theory of resonance in general; he had expressed some doubts as to whether this could ever be of any use in a system of telegraphy without wires, which seems to prove that in 1896 Tesla doubted the utility of applying the principle of resonance to anything within the limits covered by his patent;

Whereas it is true, the makers of Tesla's transformers, before selling the same, adjusted the primary and secondary elements in such a manner that if the terminals of the secondary were connected to spark balls they obtained the longest possible spark, and it has been said that this was syntonization; but, the mere fact that when the apparatus is put into use, it may be connected to any circuit whatsoever;

Whereas it is also true that when Tesla transformers are employed in a laboratory, the secondary element must be adjusted with the first, by varying the number of turns in one of the two circuits or in both until the best result is obtained, and it has likewise been said this was syntonization; but Mr. Swinburn, who has a great experience in such questions, whose evidence was taken in the English enquiry, said that he had never heard of such adjusting;

Whereas Mr. Justice Parker concludes with these words: "I can hardly admit in consequence, that it was generally [fol. 2295] known that when a transformer was employed it was necessary to syntonize the primary element with the secondary";

Whereas it is impossible to form another impression on reading the French patent of the 25th October, 1897, which

has with so much energy been pleaded as an anticipation of Marconi's patent of 1900:

Whereas, to begin with, the head note alone would make it possible to think a mistake has been made, since it reads thus: "Improvements in systems for the Transmission of Electrical Energy and Apparatus for use therein."

Whereas it is sufficient to give the wording of this specification on which the adversaries of Marconi found all their hopes in order to understand clearly that it could not constitute an anticipation, but whereas in spite of the length of this document it is necessary to quote the same *in extenso* as extracts like translations often do not do justice to the exact meaning:

Whereas it may be that misplaced confidence in isolated quotations will not deprive the deductions of Maitre Tailleur of much of their value in spite of the very convincing precision of his argument:

Whereas in fact the patent is thus worded:—

The invention which forms the subject of the present application comprises a novel method or system for the transmission without the employment of metallic line conductors, and is primarily designed for use in cases where large amounts of electrical energy are to be transmitted to considerable distances, but the results arrived at are of such character and magnitude, as compared with any heretofore secured, as to render indispensable the employment of means and appliances and the utilization of effects essentially different in their characteristics and actions from those before used or investigated.

To be more explicit I may say that the transmission of electrical energy, which forms a part of my invention, demands for the attainment of practically useful results the production and conversion of excessively high electrical pressures. Heretofore, it has been possible, by means of the apparatus at command, to produce only moderate effective electrical pressures, and even these not without some risks and difficulties, but I have devised means whereby I am enabled to generate with entire safety and ease electrical pressures measured by hundreds of thousands, and even millions, of volts, and in pursuing investigations with such apparatus, I have discovered certain highly important and useful facts which render practicable the method of transmission of electrical energy hereinafter described.

Among these facts, and bearing directly upon the invention, are the following:—

[fol. 2296] 1. That with electrical pressures of the magnitude and character which I have made it possible to produce, the ordinary atmosphere becomes, in a measure, capable of serving as a true conductor for the transmission of the current.

2. That the conductivity of the air increases so materially with the increase of electrical pressure and degree of rarefaction, that it becomes possible to transmit through even moderately rarefied strata of the atmosphere electrical energy up to practically any amount and to any distance.

The system of transmission comprised in my invention, and which, as above stated, was rendered possible only by the production of apparatus of a character radically new and different from any before known, and which is based upon discoveries made in the investigation of the results thus produced, consists in producing at a given point a very high electrical pressure, conducting the current caused thereby to earth, and to a terminal at an elevation at which the atmosphere serves as a conductor therefor, and collecting the current by a second elevated terminal at a distance from the first.

In order to attain this result it is necessary to employ an apparatus capable of generating electrical pressures vastly in excess of any heretofore used, and to lead the current to earth, and to a terminal maintained at an elevation where the rarefied atmosphere is capable of conducting freely the particular current produced; then, at a distant point, where the energy is to be utilized, to maintain a terminal at or about the same elevation to receive the current and to convey it to earth through suitable means for transforming and utilizing it.

The apparatus which I have invented, and by means of which this method of transmission may be effected, is represented in the accompanying drawing, which is a diagrammatic illustration of the system.

A is a coil, generally of many turns or windings and of very large diameter, wound in spiral form either about a magnetic core or not, as may be desired. C is a second coil formed by a conductor of much larger size and smaller length, wound around and in proximity to the coil A.

In the transmitting apparatus the coil A constitutes the high tension secondary, and the coil C the primary of much

lower tension of a transformer. In the circuit of the primary C is included a suitable source of current.

One of the terminals of the secondary A is at the centre of the spiral coil, and from this terminal the current is led by a conductor B to a terminal D, preferably of large surface, formed of or maintained by such means as a balloon [fol. 2297] at an elevation, suitable for the purposes of transmission as before described. The other terminal, that of the secondary A, is connected to earth, and, preferably, to the primary also, in order that the latter may be approximately of the same potential as the adjacent portions of the secondary, thus insuring entire safety.

At the receiving station a transformer of similar construction is employed, but in this case the long coil A' constitutes the primary and the short coil the secondary of the transformer. In the circuit of the latter are arranged lamps L, motors M, or other devices for utilizing the current. The elevated terminal D' connects with the centre of the coil A', and the other terminal of said coil is connected to earth, and preferably also to the coil C', for the reasons above stated.

The length of the high tension coil of each apparatus should be approximately one-quarter of the wave length of the electrical disturbance in the circuit \* \* \*

It will be observed that in coils of the character described, the potential gradually increases with the number of turns, and the difference of potential between adjacent turns is comparatively small, and a very high potential, impracticable with ordinary coils, may be successfully obtained.

As the main object of the invention is to produce a current of extremely high potential, this object will be facilitated by using a primary current of very considerable frequency, but the frequency of the current is, in large measure, arbitrary, for if the potential be sufficiently high and the terminals of the coils be maintained at a proper elevation where the atmosphere is comparatively rarefied, the intermediate stratum of air will serve as a conductor for the current produced, and the latter will be transmitted through the air with, it may be, even less resistance than through an ordinary copper wire.

The apparatus described, it may be observed, is useful as a means for producing currents of very high potential for other purposes than that of the present system, as, for

instance, the coils may be used singly for producing extremely high electrical potentials for any purpose, or used generally in the same manner as other electrical transformers for the conversion and transmission of electrical energy.

It will be understood that either of the coils or transformers and terminals may be movable, as, for instance, when carried by vessels floating in the air, or by ships at sea. In the former case the connection of one terminal with the ground might not be permanent, but might be intermittently or inductively established without departing from the spirit of the invention.

As to the elevation of the terminals D, D', it is obvious [fol. 2298] that this is a matter which will be determined not only by the condition of the atmosphere, but also by the character of the surrounding country.

Thus, for instance, if there be high mountains in the vicinity, the terminals should be at a greater height, and, generally, they should always be at an altitude much greater than that of the highest objects near them in order to reduce the loss by leakage. Since, by the means described, practically any potential that is desired may be produced, the currents through the air strata may be very small, thus reducing the loss in the air.

It will be observed that the phenomenon here involved in the transmission of electrical energy is one of true conduction, and is not to be confounded with the phenomena of induction, or of electrical radiation, which have heretofore been observed and experimented with, and which, from their very nature and mode of propagation, would render practically impossible the transmission of any considerable amount of energy to such distances as would be of practical importance.

To sum up, what I claim is:

1. The method of transmitting electrical energy herein described, which consists in producing at a given point a very high electrical pressure, conducting the current caused thereby to earth and to a terminal at an elevation at which the atmosphere serves as a conductor therefor, and collecting the current by a second elevated terminal at a distance from the first, as set forth.

2. A system for the transmission of electrical energy comprising in combination a source of current of very high pressure, connected respectively with earth and with a ter-

minal at an elevation where the atmosphere forms a conducting path for the current produced, a second elevated terminal at a distance from the first for receiving the current transmitted therefrom and means for utilizing the said current, as set forth.

3. The transformer herein described for developing or converting currents of high potential, comprising a low tension and a high tension coil, one terminal of the high tension coil being electrically connected with the low tension coil and with earth when the transformer is in use, as set forth.

4. The transformer herein described for developing or converting currents of high potential, comprising a low tension coil and a high tension coil wound in the form of a flat spiral, the end of the high tension coil adjacent to the low tension coil being electrically connected therewith and with earth when the transformer is in use.

[fol. 2299] 5. The transformer herein described for developing or converting currents of high potential in which the low tension coil and the high tension coil are wound in the form of a spiral, the coil of high tension being inside of, and surrounded by, the convolution of the other and having its adjacent terminal electrically connected therewith and with earth when the transformer is in use, as set forth.

Whereas not a word in this lengthy document suggests the idea that the inventor had wireless telegraphy, Marconi's invention and the theory of four syntonized circuits in his mind; whereas it is needful to seek, and indeed quite unsuccessfully, for the desired evidence that this patent left Marconi nothing to discover in this phrase which is interpreted as the organisation of adjustment, viz.: "The length of the high tension coil of each apparatus should be approximately one-quarter of the wave length of the electrical disturbance in the circuit, this estimate being based on the velocity of propagation of the electrical disturbance through the coil itself and the circuit with which it is designed to be used."

Whereas in this somewhat obscure wording it is not really possible to find proof of the plagiarism charged against the very complete and clear definition of Marconi's claim respecting the four circuits; but whereas this alleged anticipation becomes still more unlikely on continuing the

perusal of a lengthy passage, which the Court has not thought necessary to reproduce, for the single phrase which follows demonstrates the really too technical character of the same: "To maintain a frequency of 925 metres per second, maintaining 925 stationary waves in a circuit of a length of 185 miles and each wave would be 200 miles in length, I should use in each high tension coil a conductor or 50 miles in length;"

Whereas the Defendants are, as a matter of fact, quite cognizant of the inability of this patent of 25th October, 1897, to constitute anticipation and they invoke the Tesla American patent, taken out in 1897 in America and published in March and May, 1900:

Whereas the question of adjustment according to Me. Taillefer is clearer in Tesla's American patent than in 1897, but the first part of which was published, strange to say, in March, 1900 (No. 645576), before the taking out of Marconi's English patent (April), and the second part subsequently, *i. e.*, the 4th March (? May) (No. 649621), so that the patent set up is found to be precisely hemmed in one month behind and one month in front by Tesla's patent; whereas the former, by its date, might constitute an anticipation in respect of the British Marconi patent; whereas the two would constitute anticipations of the French Marconi patent applied for on 3rd November, 1900, and granted on 1st February, 1901:

[fol. 2300] But whereas both the patents bear as the title of the invention, "System of transmission of electrical energy," which already appears to overthrow this alleged anticipation, since it is a question, as in Tesla's first patent, not of wireless telegraphy, but of the transmission of electric energy; whereas this is confirmed by the concise extracts, read by Me. Taillefer, and which exclusively refer to primary and secondary, to tuning as between them, and then to syntonization and synchronism.

But whereas it cannot for one moment be admitted that in this patent Tesla had wireless telegraphy in mind; whereas he would have mentioned it together with the lamps and the motor if he had desired to consider it as one of the powerful industrial operations which currents were destined to perform; whereas it is really taking too much for granted to allege that the current designed principally to serve for electric lighting or motive power undertakings could in the

inventor's contemplation likewise be applied to the subtle and delicate action required by wireless telegraphy.

Whereas, however, the statement of the specification with regard to syntonization must be considered as the main element of the alleged anticipation of the Marconi patent, while the opponents of Marconi are seen to be maintaining that this element of his patent possesses no scientific value, and in fact does not exist; and that by a fresh change of front they will combat the charge of infringement by maintaining that the Marconi apparatus has indeed four tuned circuits, whereas the appliances seized have not, and are in fact apparatus guiltless of any infringement;

Whereas this oscillation of truth, wavering according to the exigencies of the various arguments, is a matter that should be chronicled in so subtle an enquiry as that submitted to the Court;

Whereas the second patent of 15th May, in the first place, raises a very interesting question which has never yet been decided, viz., that of priority;

Whereas indeed this patent was published, as has just been observed, within the interval separating the taking out of Marconi's English patent, and that of the French patent of 3rd November, that is to say, in the period of priority which makes the new intermediate patent inopposable to the one which comes into being before this patent and terminates subsequently;

Whereas this period being six months, had expired on the 3rd November for the Marconi patent, and took away from it the benefit of priority as against the Tesla patent;

But whereas on the other hand, this period, which is now uniformly extended by the Brussels Conference to twelve months, was according to the 1883 Convention, limited to six months for the countries of Europe, whilst it was seven [fol. 2301] months for oversea countries, and that therefore the question as to whether the second Tesla patent is an admissible, if not an operative anticipation of the Marconi patent of 3rd November, depends upon determining whether or not England is an oversea country;

Whereas although manifestly England is separated by salt water from France and from the Continent of Europe generally, yet she could not on that account, even less than Corsica, Sardinia, Algeria, Tunisia, Morocco, Egypt, etc., be regarded as excluded from the European family and exiled to those remote and mysterious regions recalled by

the somewhat archaic term out of which the difficulty arises:

Whereas the confirmation of this opinion is that the Rome Conference in 1886, having for its object the working out of explanatory regulations as to the 1883 Convention, drew up paragraph 2 of the chapter entitled "Explanatory Provisions": "As regards the States of the Union situated in Europe, the Extra-European countries which do not border upon the Mediterranean are considered as oversea countries";

Whereas Algeria, Morocco and Egypt are not regarded as oversea countries, and it appears difficult to consider England as an oversea country, being connected with our coast by the various schemes: A submarine tunnel scheme now in preparation, wireless telegraphy and aerial navigation that are actually accomplished facts. And it is all the more difficult in view of the wording set out above, as England not bordering on the Mediterranean, although forming part of the States of the Union situated in Europe, would find herself in the paradoxical position of being to herself her own oversea country;

Whereas, therefore, in this case the period of priority must only be six months, it follows that the Tesla patent of 15th May might anticipate the Marconi patent of 3rd November as well as the first Tesla patent of 20th March;

Whereas, furthermore, the question was not of great importance; indeed, as has already been seen, the Tesla patents could not form an anticipation of the Marconi patent by reason of the profound difference of the application of the two opposed systems: That of Tesla to great industrial operations requiring powerful electric circuits; lighting and power, and that of Marconi having no other objective but telegraphy by Hertzian waves;

Whereas, however, Me. Taillefer maintains the argument of anticipation with great energy; but in order to follow him in his reasoning, supported by fragments of patents, it would be necessary to examine the twenty-four pages of the Tesla patent; whereas Me. Taillefer has himself understood this as his contentions of 12th November thus summarises the arguments of his pleading of the 9th:

[fol. 2302] "It appears from the patent that Tesla had in view the transmission of electric energy to a distance: For this purpose he transmits by induction to an antenna circuit high pressure electric current generated in a first

circuit, which is so arranged that the primary of a transformer, situated in this first circuit, is surrounded by the secondary of the same transformer appearing in the antenna circuit.

"At the other end, at the receiving apparatus, the antenna circuit, under similar conditions, excites by induction a second circuit comprising either lamps or motors or any other apparatus for making use of the transmitted energy. Tesla in his patent indicates in the clearest manner that the various circuits he employs must all be tuned together to corresponding wave lengths; that is to say, syntonized; and that thus, just as with Marconi, the various circuits made use of are arranged in like manner, and are tuned both two and two and all together;

On the other hand, Tesla states that the system that he recommends can be employed for the transmission of intelligible messages to a distance; that he, therefore, certainly has in view the possibility of its application to wireless telegraphy by the aid of high frequency electric waves.

"The object is, therefore, quite the same as that pursued by Marconi and the conditions of carrying the same out are likewise similar; that therefore the Tesla patent of 20th March constitutes an absolute anticipation in all its parts of the Marconi patent."

Whereas these contentions do not go beyond assertions that are at times fairly vague and overlook all the objections doubtless because the very precise mind of their author comprehends the full seriousness of them;

Whereas the contentions of the Société Radioélectrique are bolder, defining, as they do, their points in these terms:

This system consists of the combination of four circuits, one transformer at the transmission, a high frequency oscillation circuit and an antenna circuit; two circuits of one transformer at the receiving station, an antenna circuit and the circuit containing all the translating and registering apparatus; these four circuits are adjusted so as to ensure the synchronising of the oscillations of varying means of capacity and inductances.

Whereas this concise summary could not take the place of the lengthy wording of the specification, which was not translated and which, therefore, evades the examination of the Court, an abnormal position, which is possibly an

avowal of the small degree of reliance placed upon a document, produced at the last moment, and which nobody had [fol. 223] till then thought of, by the Société Radioélectrique and the other Defendants, which fact should make one very sceptical as to its value;

Whereas, therefore, the Court, being placed in the position of not being able to examine the wording of the patent invoked, restricts itself to noting the profound difference existing between the interpretation of the patent by the Société Radioélectrique and its interpretation by the Société Radiotélégraphique; as nothing in the cited extracts permits of assuming any analogy whatever between the Tesla patent and the Marconi patent;

Whereas, further, it could not well be otherwise; for manifestly, as has already been pointed out, the American patent only has in view a new means of conveying light and power to long distances, without the very costly metallic conductors, in order to be used for industrial purposes properly so called; whereas doubtless vague references are made therein to the transmission of intelligible messages, but the language being, so to speak, with evident intention couched in vague terms, cannot be considered as imparting to the patent the character of a wireless telegraphy invention; moreover it is difficult to see how a device capable of conveying currents at a high voltage, and intended for continuous lighting or motive action, could be made suitable to the special requirements of transmitter and receiver, providing the intermittent but repeated action requisite for the working of wireless telegraphy with manipulators;

Whereas, further, the device of the American patents, as is admitted, comprises neither spark producer nor spark, nor detector nor reflex system, which are the fundamental bases of wireless telegraphy; and whereas it operates by phenomena of conduction, which is entirely different from radiation phenomena, and by means of powerful currents instead of Hertzian waves, which have led to the idea of wireless telegraphy and have ensured its marvellous working;

Whereas the examination of the engravings attached to the patent shows still better, if possible, the absence of any analogy between the Tesla and the Marconi patents;

Whereas certain vague details, sheltered from all examination or investigation, such as the syntonization alleged

to be identical with that of Marconi, cannot support an admission that this document, produced at the last moment, is of the least value for the purpose of assimilation with the Marconi patent.

Whereas this conclusion presses itself with special weight when it is considered that it was in the course of discussion, or rather at the end of the discussion in November, 1912, that these patents, which lay dormant and forgotten in America from 1897, re-awakening in France in 1900, and for twelve years resuming a condition of inertia, have suddenly put in an appearance;

[fol. 2304] Whereas Tesla appears to have been of the same opinion; that as a matter of fact, it is fitting to recall to his honour, that as early as the year 1892, he had pointed out that an arc fed by a continuous current could take the place of the Hertz exciter, if placed within a powerful magnetic field, which phenomenon led to the discovery of wireless telegraphy by means of the singing arc, which is it appears one of the systems of the Société Radioélectrique; and whereas the following year, at a lecture given before the Franklin Institute, Tesla, the first to follow Popoff, had the idea of utilising high frequency currents for the transmission without conductors of intelligible signals and possibly of also energy; and whereas the patent of 1897 transposed matters, being almost entirely confined to the conveyance of industrial energy, and on the other hand relegating the idea of communications by signals to the rank of hypothesis, the interest of which was not foreseen;

Whereas evidently this scepticism of the author with respect to wireless telegraphy set him apart from the very powerful movement that took place with regard to this new science; and thus he restricted himself to the invention of the transformer which bears his name and which precisely was adopted by the one against whom his patents are invoked;

Whereas in the excellent work of Commander Ferrier, nothing else is to be found regarding a scientist of such attainments; and whereas he never made any attempt connected with wireless telegraphy; and he had thus himself repudiated beforehand the character which it is desired wrongly to impute to the American patents;

Whereas further these patents, even if they were foster parents of wireless telegraphy by any process whatever,

would be too distinct from the Marconi patent to constitute even the shadow of an effective anticipation;

Whereas after this last defeat of its adversaries, the Marconi patent stands out as an unassailable monument until new discoveries are made, but which so far from claiming a *de facto* monopoly, must consider the Defendant Companies as meritorious, sympathetic and necessary rivals, inasmuch as they produce the emulation which is indispensable to progress, and is consequently for the public benefit;

Whereas all credit should be given to the intellectual energies which apply themselves to these peaceful struggles without the abuses, the injurious actions and the violence which are so frequently engendered by too passionate rivalries;

#### Part Fourth: Cancellation

Whereas Marconi's adversaries invoked against his 1900 patent the trifling objection that it had not been worked within three years of the grant of the patent; whereas the considerable effort devoted to anticipations has caused that [fol. 2305] which ought reasonably to occupy the first rank to be relegated to the second; whereas, therefore, the prominent place given to the discussion of the anticipations should be considered as a actual renunciation of the objection of non-working; whereas, however, this objection being maintained in the submissions and the pleadings, it is necessary to examine the same, however paradoxical it may be; whereas in fact it is well known that hardly had the invention of his genius seen the light when Marconi witnessed its eager and unanimous adoption;

Whereas, therefore, it was almost unnecessary to produce the letter of the Compagnie Générale Transatlantique as follows:

The Compagnie Générale Transatlantique certifies that wireless telegraphy appliances on Marconi's system were installed upon "La Savoie" in 1902, upon "La Lorraine" on 5th March, 1903, upon "La Touraine" on 27th June, 1903, and that these appliances are at present still being worked upon the said mail boats.

Whereas this proves that the patent applied for on 3rd November, 1900, and granted on 1st February, 1901, was

worked within the three years, and that under such perfect conditions, that the powerful Compagnie Transatlantique had no hesitation in equipping their great vessels with same, and that the original device still gives entire satisfaction after the lapse of ten years:

Whereas, indeed, one of the opponents of Marconi objects that the Plaintiffs, acting on the strength of Marconi's rights, only at a recent date established in France works for the manufacture of plates, wires, cables and other articles serving for the working of the patent; whereas the Société Radiotélégraphique even had recourse to a proceeding that Me. Seligmann rightly describes as somewhat barefaced, viz., that they enticed away one of the employees of the Marconi Company, who with the aid of subsidies from the young rival company is said to have photographed certain elements of construction which would appear as being of British manufacture:

But whereas, even if the parts which the Marconi Company makes use of to construct their highly important stations and hence to work the patent were wholly obtained from sub-contractors, that would be no matter of reproach to the Plaintiff Company; the Marconi patent being, as a matter of fact (and the opponents have maintained this to the extent of accusing Marconi of being an audacious plagiarist) only a patent relating to the combination of known elements and consequently Marconi has every right to obtain his materials from the firms that manufacture them; and whereas the manufacture, application and working the patent consists of obtaining, wherever the Company may think proper, if it is not thought advisable to undertake the manufacture thereof themselves, the cables, plates, accumulators, coils, &c., which when combined will set up wireless [fol. 2306] telegraphy stations with syntonized circuits:

Whereas this manufacture, and, it may be added, this French manufacture, is proved, especially by the two agreements entered into between the Marconi Company and the Compagnie Transatlantique in 1901 and 1903; and whereas in the former the following is to be found:

The Marconi Company shall instal at their own expense their wireless telegraphy apparatus upon the mail boats of the Compagnie Transatlantique performing the service between Havre and New York, and by mutual agreement the "Savoie" and the "Touraine" have been selected.

Art. 4. The plans shall be submitted to the Compagnie Transatlantique for approval; the Compagnie Transatlantique shall not further have to intervene in the working of the stations installed by the Marconi Company, &c. . . .

The Compagnie Transatlantique shall gratuitously supply the assistance of their staff of laborers and of their workshops for the repair and future maintenance of these stations, in so far as such assistance may be compatible with the requirements of the service of the Compagnie Transatlantique.

Whereas in the second the following is to be found:

The demonstration to which reference is made in Art. 15 of the contract of 1901 having proved satisfactory to the Compagnie Transatlantique, the two Companies putting into operation the other articles of the contract resolve as follows: . . . The maintenance of the station on "La Savoie," the installation of a second and third station.

Art. 15. The Compagnie Transatlantique shall participate in the expenses incurred by the Marconi Company in equipping electric plant to the extent of 2,500 francs per station; this sum shall be reimbursed to them under such and such conditions, &c. . . .

Whereas the foregoing affords evident proof of manufacture in France, by French labour, and which was continued in 1903 by the Compagnie Française Maritime et Commerciale de Télégraphie Sans Fil, which was licensed by the Marconi Company, and which since that time has without interruption been engaged in industrially equipping the fifty or more mail steamers which are at the present time equipped or ready to be equipped with the patented apparatus;

Whereas this proof is in itself sufficient and in denying same the Defendants thereby become Plaintiffs and take upon themselves the onus of proving their assertion, which they have not done;

Whereas it was therefore needless for the Plaintiffs to produce among other documents the invoice of the Société Industrielle des Téléphones, dated 13th February, 1902, and [fol. 2307] proving the supply of special cables, of a special key for the condenser, of a box for the condenser, of a roller and of a piece of mahogany cabinet work for wireless telegraphy in accordance with a model returned.

## Part Fifth: Infringement

Whereas the Société Générale Electrotélégraphique and the Société Française Radioélectrique, as a matter of course, each on their own part maintain, alternatively to their claims for the cancellation of the Marconi patent, the dissimilarity between the appliances covered by this patent and their apparatus which was seized;

Whereas the Société Radiotélégraphique rely, with regard to the actual seizure effected at Marseilles, upon the interesting statement dictated to the bailiff by the expert whom he took with him;

I ascertained the existence of a wireless telegraphy station, working as stated hereinafter:

### 1. Transmission (Fig. 1 of the sketch):

The energy in the form of alternating current is produced by a converting group, the alternating current thus produced feeds, through the medium of a Morse key manipulator, the primary P of the static transformer T<sup>r</sup>; the secondary S of this transformer is connected with the coating of a condenser C, forming part of an oscillating circuit called the primary oscillating circuit, comprising in addition the spark producer or oscillator and the self-induction L.

This circuit acts by indirect excitation by derivation upon a second circuit called "secondary circuit or antenna circuit"; this second circuit comprises the adjustable antenna inductance I; the self-induction L<sup>1</sup>, and the earth T. The two self inductions L and L<sup>1</sup> form a genuine transformer.

The self-induction L and the capacity C of the primary oscillating circuit have suitable values to permit of the establishment of definite periods in this circuit of oscillation; the circuit of the antenna is regulated upon the period selected for the primary circuit by means of the antenna inductance.

### 2. Receiving station (Figure 2 of the sketch).

The arrangement again comprises two circuits: the antenna circuit and the detector circuit.

The antenna circuit comprises the antenna proper A, which is a real portion of the antenna inductance B, and an adjustable condenser C; the detector circuit comprises the adjustable self induction B<sup>2</sup> and the four detectors D<sup>1</sup>, D<sup>2</sup>, D<sup>3</sup>, D<sup>4</sup>, and the adjustable condenser B<sup>1</sup> and B<sup>2</sup> form a genu-

ine transformer or first regulates the antenna circuit according to the period of the oscillations.

Whereas it is precisely upon these submissions that the Marconi Company base their accusation of infringement [fol. 2308] against the Société Radiotélégraphique;

Whereas the Marconi Company profess to discover:

(A) In the description of the source, at the transmission station, the regulation of the antenna circuit upon the oscillation circuit; at the receiving station, the regulation of the detector circuit upon the antenna circuit; that is to say, the four circuits of Marconi;

(B) In the transformer, the primary circuit, wherein are inserted the condenser and the spark producer, the primary circuit being thus the well-closed oscillator of Marconi;

(C) The secondary circuit, antenna circuit connected to the primary circuit by a transformer as in the Marconi arrangement;

(D) The two self inductions L and L', forming a genuine transformer;

(E) The two circuits of the transmitter tuned together, the self induction and the capacity of the primary circuit having suitable values, in order to permit of the establishment of definite periods, it being unnecessary that they should be exactly the tone value figures of the Marconi patent, these figures being merely examples, whereas the provisions of the two appliances, the patented one and the seized one, are identical;

(F) The antenna circuit being regulated—and this is the main point—upon the period of the primary by means of the adjustable inductance, which does not exist in any anticipation, and is therefore the characteristic feature of the Marconi patent, and consequently, of its infringement;

(G) At the receiving antenna, also two circuits; That of the antenna and that of the detector connected by a transformer;

(H) Two adjustments: That of the antenna circuit upon the period of the oscillations given by the transmitter, then the circuit of the detector regulated upon the antenna circuit;

(I) To sum up, the four tuned circuits, which are precisely Marconi's invention;

Whereas the submissions of 14th October, 1912, of the Compagnie Générale Radiotélégraphique, in reply to these arguments, have been powerfully developed and commented upon by Me. Taillefer;

Whereas doubtless he duly recognises in the apparatus seized, practically everything that Me. Seligmann discovers therein as elements of infringement, but with scientific negations and important differences; whereas he thus formulates the first point of the defence:

I have already had occasion to point out that this formula is incorrect, and that the period of oscillations of the receiver was never regulated upon the period of oscillation of the transmitter, which is by its side. They are never [fol. 2309] together. Adjustment is effected upon any transmitter such as the one sending the message, that is to say, an attempt is made to perceive by sounding in space; or it may be, if regulation is properly effected, a noise is vaguely heard, and an attempt is made to catch this sound until the maximum physiological sensation is attained, that is to say, the most complete hearing. And I have pointed out that when one thus has electrolytic detectors, it would be impossible to know, otherwise than by rule of thumb, how one is to effect the tuning of the circuits; and I was saying that with the electrolytic detector, when the physiological perception is at its maximum, it never corresponds to an exact tuning of the circuits, for the electrolytic detector possesses this special feature, that it gives maximum effects when the energy transmitted to it is likewise at its maximum. Very well, the energy transmitted when it is at its maximum does not at all correspond to a tuning of the circuits. The result of this is that this tuning of the circuits, in the sense of the rule LC, equals constant, is never accomplished in the incriminated apparatus.

Whereas Me. Taillefer subsequently gives in the following terms the concise but vigorous enumeration of the differences he believes he can find between the two sets of apparatus in question:

**Transmitter.** In the case of the Radio-Télégraphique, feeding by alternating current; in the case of Marconi, continuous current.

In the case of R.T. the antenna is in derivation and forms a part of the second spark producing circuit; in the case of

The total of the appliances and their connection has lead to the conclusion that their employment must be carried on under the following conditions:

The energy in the form of alternating current is produced by the high frequency converter group; the alternating current thus produced feeds, by the intermediary of a manipulator, the primary of a static transformer; the secondary of this transformer is connected to the coatings of a condenser  $C$ , forming part of an oscillating circuit, called the primary oscillating circuit, comprising in addition the spark-producer or oscillator  $E$  and the self-induction  $L$ ; this circuit acts by indirect excitation by derivation upon a second circuit called the secondary circuit or the circuit of the antenna; this second circuit comprises the adjustable antenna inductance  $L$ , the self-induction  $L^1$  and the earth  $T$ , the two self inductances  $L$  and  $L^1$  constitute a genuine transformer.

The self-induction  $L$  and the capacity  $C$  of the primary oscillating circuit are of suitable values to permit of the establishment of oscillations of determinate periods in this circuit; the antenna circuit is regulated upon the period selected for the primary circuit by means of the antenna inductance  $L$ .

[fol. 2311] 2. The existence of an electrolytic receiving system and the general nature of the connection has led us to the conclusion that the employment of this receiving system must be effected under the following conditions:

There are again two circuits.

The antenna circuit comprises the antenna proper  $A$ , a variable portion of the antenna inductance  $B$  and the earth  $T$ ; the detector circuit comprises an adjustable inductance  $B^2$ , a variable capacity condenser  $C$  and the detector  $D$ .

The union of the two inductances  $B^2$  and  $B^1$  forms a genuine transformer. In the first place the antenna circuit is regulated upon the period of the oscillation given by the transmitter, whereupon the detector circuit is adjusted upon the antenna circuit.

We have noticed that on the converter group there appears a plate bearing the following inscription; Société Française Radioélectrique, 128, Rue de la Boétie, Paris.

Whereas Mr. Seligmann in his very masterly argument after this quotation discussed certain very important points

of the question, and any possible objections in the course of a dissertation dealing with the two seizures; but whereas it is convenient, before dealing with his argument, to set forth the objections of Me. Sarraute on behalf of the Société Française Radioélectrique:

Whereas the attack opens by charging the Havre Bailiff with having acted improperly; whereas if, in fact, he found an Oudin apparatus, an Oudin resonator at the transmission station, he calls attention to a Tesla transformer at the receiving station; an installation by induction and two separate circuits; whilst there were in reality both at the transmitter and the receiver an Oudin autotransformer as in the Dueretet arrangement, which, again, will be brought forward here, as well as in the question of anticipation, as an argument regarded as decisive against Marconi; but whereas the Bailiff overlooked this second autotransformer by not forcing open the box containing this same, so that acting upon inference and not upon experiment he asserted the existence of a Tesla and two circuits, whilst there was an Oudin and one single circuit; whereas, further, the Bailiff is alleged to have also committed a gross error in referring to an apparatus working by induction whilst it operated by derivation;

Whereas, however, Me. Sarraute acknowledges that the substitution of the Oudin for the Tesla is unimportant as compared with two main facts deposed by the bailiff, which were sufficient to defeat Marconi; an Oudin resonator at the transmission circuit, an electrolytic detector at the receiving circuit, which would make the apparatus a derivative, not of Marconi, but of Dueretet, who would thus find that he had successfully overcome in advance the opponent whose system, being essentially based upon the tuning of [fol. 2312] four circuits, could not be said to be infringed by a system which only tunes three, inasmuch as the Oudin resonator inserted in the transmitter between two circuits which it tunes first together, and then with that of the antenna, would in fact form only three synchronized circuits; whereas indeed the circuit of the detector is not only tuned with those of the transmitter, but, further, cannot be adjusted to resonance, and, therefore, there is no fresh analogy between the apparatus seized and the patented appliances;

Whereas it is sought to explain this difference by the difference alleged to be very profound between the Braulty

detector, the only one which existed in 1900, and the electrolytic detector which the Defendants employ;

Whereas this term and this system, which play such a great rôle in this portion of the discussion, require some comments, without which the arguments would be difficult to follow.

Whereas Me. Taillefer began this examination at the outset of his pleading by opposing to the Branly detector, which is particularly subtle and subject to wave influence, another more recent system; the electrolytic detector, which is alone implicated and the crystal detector, which has already been referred to; whereas the electrolytic detector is, according to Me. Taillefer, a species of voltmeter of a very delicate character, consisting substantially of two platinum wires, the finer one of which provides by its two ends the two poles of the voltmeter, which is very sensitive to external waves; whereas, if it is influenced by the latter, the current readily passes through, but it does not transmit the same unless the intensity of these waves reaches the maximum, so that it does not work if the circuits are tuned;

Whereas under these conditions it may at once be asked whether the system of the Société Radioléctrique is nothing more than misapplied genius, and an endeavor to differentiate itself from the Marconi system, which retains its paramount value and which a detail of this character cannot detract from;

Whereas this opinion appears to be corroborated by the following extract from the excellent work of M. le Commandant Ferrier, who associated himself with Commander Tissot in the present proceedings against Marconi, to whom he had as recently as 1909 rendered striking homage; whereas in fact, on pages 310 and the following of this book, composed with the collaboration of Colonel Boulanger, the following explanation of the electrolytic detector is to be found, following upon that of the metal filing coherer, and the magnetic receiver, which is increasingly adopted by Marconi, and the Stuby and Telefunken receiver:

All the electrolytic detectors and receivers are constructed on the same principle, and are only differentiated by their details.

In the direct action arrangement the detector is put in [fol. 2313] circuit with two telephones, and the resistance of a potentiometer fitted upon a cell. A slider enables the

electromotive power applied to the terminals of the detector to be varied at will.

An adjustable condenser is applied to the terminals of the detector; the detector is directly interpolated in the antenna, to which are added a self-induction and an adjustable condenser, both being for the purpose of obtaining resonance.

This arrangement is rarely employed except in very simplified stations.

For indirect action by derivation the detector is fitted, as in the previous case, with the telephones and the potentiometer. A solenoid has one of its ends connected to the point of the detector, the other end being free. Two sliders can be moved along the solenoid: A is connected to the aerial, B to earth and to one of the coatings of a condenser, which may or may not be adjustable, the other armature being connected to the second terminal of the detector. The primary of the resonator is therefore formed by the turns A B and the secondary by the turns B<sup>2</sup>. The sliders are sometimes arranged so as to permit of their being rendered interdependent; they are first set in motion one after the other, then together in order to find the position which gives the best receptivity, or which permits of eliminating any kind of disturbance. When the condenser is adjustable, it is necessary to add to the foregoing adjustments that of this condenser. Another adjustable condenser is also sometimes placed at the terminals of the detector to reduce the damping of the circuit of resonance.

Each receiver generally comprises several detectors which are at will placed in circuit by means of a commutator.

The circuits of the detector, and in particular the earth wire, should be disconnected during transmission in order to avoid rapid deterioration of the detector.

Finally, the arrangement for indirect action by induction does not differ from the foregoing except as regards the resonance circuits.

As a rule the secondary is not adjustable. To pass from one scale to the following a change of secondary is made. The waves comprised between those corresponding to two secondaries are brought into resonance by means of adjustable condensers.

The primary is ordinarily adjustable by means of a slider or with the aid of plugs.

The secondary can likewise be set up in the detector circuit.

As a rule, the coupling is regulated by modifying the distance between the primary and the secondary.

[fol. 2314] Superfluous and extraneous signals are successfully eliminated by making use of an intermediate circuit, the coupling of which can be varied with the aerial circuit and the detector circuit.

The purifying function of these intermediate circuits has been pointed out by Mr. Stone in respect of both receiving and transmission. They are subject, however, to the drawback of absorbing a portion of the energy, but in many cases this fact does not give rise to any serious inconveniences, whilst on the other hand it is very important to clearly receive signals which are rendered indistinct by extraneous signals or atmospherical disturbance.

For instance, the mode of erection shown on Figure 167 can be made use of, the various condensers being adjustable as well as the various windings. It is well to arrange a commutator in order to permit of using at option one only of the circuits instead of both.

Whatever may be the mode of erection adopted for putting the electrolytic detector into operation, the apparatus to be made use of can be of any pattern. However, to obtain the maximum efficiency it is advisable to observe the following rules, &c."

Whereas from this long quotation, which in case of need may be corroborated by pages 145 and the following from the same work, several facts are made manifest, the first of which is that the electrolytic detector does not in fact present any serious differences as compared with other detectors; the second is that the processes of induction and of derivation are comprised in the same devices; the third is that the question of adjustment is always the dominant one in wireless telegraphy whatever may be the differences existing in the various parts which combine to produce the common result; whereas, further, one is somewhat surprised to observe in this portion of the contest, which is devoted to infringement, the energy displayed in rejecting the possibility of tuning the circuits, whereas when dealing with anticipations it was sought with equal energy to prove that everybody had known and made use of syntonisation prior to Marconi, who was accordingly merely a plagiarist with his theory and practice of four circuits;

Whereas it is opportune to confirm the foregoing by one of the passages from Me. Taillefer's pleadings:—

In Tesla there are four circuits tuned with a view to the transmission of wireless telegraphy;

By whatever means Tesla's theory is carried out, whether by Marconi waves, whether by Tesla or Hertzian waves, all this is merely a matter of words, and we are compelled to face the facts.

Very well, you acknowledge that in Tesla there are four tuned circuits, tuned not only in pairs, but all four together; that they transmit electric vibration from end to end, and that, as pointed out by Tesla, they can be used for the purpose of wireless telegraphy. I want to know what there is remaining of the Marconi patent.

Whereas, however, the Defendants seek to demonstrate that there is a sufficient difference between the apparatus seized and that of Marconi, owing to the fact that in the apparatus of the latter the transformer is composed of two entirely distinct coils, whilst the transformer of the seized appliance is formed of one single coil, one portion of which contains the primary circuit in which the current passes; that this single self-induction coil also contains the transformed current of the secondary circuit in the shape of radiation current; that thus the action of the primary circuit upon the secondary circuit is alleged to take place not by induction as in the case of Marconi, but by derivation, which is expressed by stating that the apparatus seized is not a transformer like Marconi's, but an auto-transformer, which would suffice to cause the complaint of infringement to fall to the ground.

Whereas these subtleties appear to be irrelevant inasmuch as in the first place the Marconi claims do not define the transformer he proposes to use, but in his improvement patent are made applicable to all systems of transformers, so that he can equally well make use of the Tesla device adopted by him and the Oudin device, which would distinguish the seized apparatus.

Whereas further the contradiction which it is sought to establish between the transformer and the auto-transformer is scarcely more than a dispute about words; whereas, indeed, the term "transformer" was at the outset made use of to designate the apparatus serving to raise or diminish the voltage of an electric current, for instance,

by converting a current of 30 amperes at 100 volts into a current of 10 amperes at 300 volts or *vice versa*; and whereas the apparatus principally used at the outset had two separate windings and the ratio in which the voltage was raised or lowered depended upon the number of windings of the secondary as compared with the number of windings of the primary:

Whereas this apparatus was employed for other purposes than that of modifying the voltage and particularly for the transformation of electric energy into the energy of the magnetic field, the latter in turn becoming transformed into electric energy in another circuit, *i.e.*, in the secondary as an induced current:

Whereas the same effect could be obtained subsequently by an apparatus having one single winding, one portion of which only is common to the two circuits, and the whole or a part of which was placed in one only of the two circuits; whereas the ratio of change in the voltage depended upon that existing between the number of windings of the primary and the number of windings of the secondary:

Whereas this apparatus, which was first called a transformer, received the name of auto-transformer in order to distinguish it from the transformer proper, having two separate windings:

[fol. 2316] Whereas the supporters of a marked difference between the two systems allege that the auto-transformer does not act as does the transformer entirely by mutual induction, but partially by mutual induction and partially by what is called inductive derivation; so that they can entirely eliminate mutual induction in order to obtain inductive derivation only, which would constitute a genuine invention; -

Whereas there must be pointed out what is of great importance to the discussion, that if in an auto-transformer the whole of the winding is common to the two circuits there is no modification of voltage and consequently no effect by way of transformation of voltage, but the only function of the apparatus is by way of inductive derivation;

Whereas prior to Tesla's experiments upon high-frequency currents and very high potentials, the transformers and auto-transformers were provided with the traditional iron core, offering a more ready passage to the lines of force of the magnetic field; but whereas Tesla in order still

further to increase the voltage made use of transformers without core, which were definitely adopted in his patents of 1898 and 1899 and were, doubtless, also contemplated in the more general description of the 1900 specification:

Whereas the Oudin transformer appears to have been the only apparatus without a core employed prior to Marconi.

Whereas Commander Ferrier, on page 223 of the book already referred to, under the title, "Oudin and Tesla Transformers," examines the two appliances under discussion and which thus appear as possessing very great analogies;

Whereas under such circumstances, it can readily be understood that the learned Me. Taillefer should express himself thus:

I take it that the Oudin resonator is a transformer; it is a further transformer. \* \* \* the adjustment of the aerial is effected by the employment of the Oudin transformer. \* \* \* and this is interesting, for in the device impeached by Marconi we discover precisely the aerial and the employment of the resonator. Oudin uses it with the same object and for the same purpose.

For what purpose, then, is my opponent's lengthy dissertation to demonstrate that the Oudin resonator and the Marconi transformer are the same thing? I am in agreement with him \* \* \* Marconi, in 1900, copied Lodge, Braun and Tesla; he further borrowed from Oudin that which was his characteristic feature \* \* \* in 1898 the transmitter (Marconi) is provided with an Oudin adjustable resonator.

Whereas it is evident from all the foregoing that the substitution of an Oudin for the Tesla in the seized apparatus does not constitute any palliation for those who are charged [fol. 2317] with infringement, as Marconi, as a matter of fact, employed the Oudin transformer or auto-transformer prior to 1900 and on the strength of his claims can still do so, seeing that the practical result is the same;

Whereas the excuse of incomplete syntonization in the apparatus seized as compared with the four Marconi circuits also falls to the ground in presence of the foregoing findings of fact; whereas scientific theories, however ingenious they may be, which attempt to make out that Marconi's formula of mathematical syntonization is inappli-

cable, as well as the impossibility of the seized apparatus providing the syntonization of four circuits, also fail in view of the results of the Marconi invention, the identical working of the seized apparatus, which would not be the case without syntonization, which is the fundamental basis of a practical receiver for Hertzian waves:

Whereas it matters little whether such syntonization be the result of a mathematical formula or of the employment of adjustment by a tentative method, as Nature almost always takes an ironical pleasure in defeating absolute classification as well as any attempt to imprison it within infallible dogmatic formulæ; whereas the supporters of such formulæ, who try to set up Oudin in opposition to Tesla, derivation to induction, and the couplings of the seized apparatus to those of Marconi are entirely routed by Commander Ferrier, to whom the involved Companies appeal, and who, in his learned developments of Chapter VIII. of the work already referred to, absolutely assimilates the indirect processes of excitation, induction or derivation in respect of both the receiver and the transmitter:

Whereas the simplest method in this grave discussion is to quote verbatim concise extracts which will provide an irrefutable argument upon the point in dispute:

Indirect excitation by derivation. . . . This excitation is identical with the equation we have laid down for coupling by induction . . . in both cases the co-efficients representing the ratio of the self-induction of the coupled portion to the total self-induction of the aerial.

We can therefore apply to excitation by derivation all the conclusions which have been laid down for coupling by induction . . . the circuits are in resonance. . . .

To sum up, the following adjustments will have to be carried out:

In the case of the transmitter the two coupled circuits must be brought into resonance and the same thing applies to the two receiving circuits. . . .

It is by tentative methods that these various adjustments are effected. . . . In the case of the receiver preference is given to operating by induction, as the adjustments are far more precise when the circuits are entirely separated [fol. 2318] Whereas in any event, whether the seized apparatus formed a part or a working detail different from

the whole appliance constituting the 1900 Marconi patent, infringement would none the less exist on account of this fundamental law in respect of patents, viz., that any one borrowing the principle of a patented invention cannot evade the consequences of his infringement by introducing unimportant modifications into the invention; and whereas when the invention, as in Marconi's case, covers a combination of parts or a process producing new and useful results, any one producing the same results by making use of the main parts of the combination of the process infringes the invention, even if he has modified the combination of the process by omitting some unimportant part and substituting another equivalent part;

Whereas in the case of the seized appliances, in order to evade the complaints brought against them, it cannot be alleged that they had invented a new process as regards Marconi's process; whereas, as a matter of fact, the latter has not yet been surpassed, as Commander Ferrier acknowledges, not in his statement brought into the discussion in so unexpected a fashion that Mr. Taillefer did not think fit to rely upon him, but rather upon the formal declaration to be found on page 403 of his work already referred to and which reads as follows:

It was in 1896 that Mr. Marconi accomplished the first communication by means of Hertzian waves; since that time he has continued to improve his earlier devices, and it may be said that he is still at the present moment, among all the scientists dealing with wireless telegraphy, the one who has caused the greatest advances to be made.

In 1899 the establishment of radiotelegraphic communication was the first real practical application of wireless telegraphy.

The first experiments of syntonized apparatus were made by Mr. Marconi between France and Corsica.

Whereas to sum up, so long as those who profess to obtain the same practical result as Marconi have not discovered fresh processes, but restrict themselves to introducing insignificant variations in his apparatus, they will not be able to escape from the reproach of infringement;

Whereas it is surprising to read immediately afterwards a special notice stating precisely that his system cannot be regarded as an infringement of the Marconi patent; whereas one is still more surprised to observe that the Com-

pagnie Radioélectrique, in view of their contradictory attitude, have not thought of proving that the apparatus seized against them were not their property.

[fol. 2319] Part Sixth: Summing Up. Judgment

Whereas, to sum up, this lengthy examination of the facts and of the arguments of the parties, of the documents which are for the most part very largely quoted from in order to avoid any unintentional colouring of their wording or their intention, has made apparent the unquestionably novel character of the 1900 Marconi patent; whereas doubtless the latter has drawn from the common fund of knowledge the various elements of his invention, which has no pretence to be anything else but the application of known means for the achievement of a new industrial result;

Whereas, however, in spite of the high status of the scientists whose partial discoveries it has been sought to put forward as anticipations fatal to the Marconi patent, the latter is none the less the one who first occupied and maintained an important position not only in the practical utilisation, but also has already been seen in the search for constant improvements;

Whereas, doubtless, the powerful combining process which enabled Marconi to bring the result of all previous scientific and practical research to such a high level is the most valuable testimony rendered to the genius of his predecessors, but does not in any way detract from the operations carried on by him which brought into the domain of the most remarkable industrial application all the efforts which had remained at a standstill on the purely scientific territory of theoretic ideals or on the less attractive ground of incompletely successful inventions;

Whereas in view of the tremendously rapid march of science, which is constantly placing within the reach of all, as a conquest, which quickly becomes commonplace; that which perhaps not long before appeared to be the boldest of vain imaginings, it cannot be doubted that within a short time wireless telegraphy, according to Marconi's patent, will seem but a modest preface to fresh conquests, but whereas this development, the fruit of further efforts, which will perhaps give to the conquerors of new forces, as compared to Marconi himself, the privileged position which he has inherited from his predecessors, does not

detract at all from the glory of the past, which is the common patrimony of all labourers who are early in the field.

Whereas in view of these natural laws which exert a sovereign dominion over the mysterious destinies of humanity, it will be safe to relegate to a negligible background the passions which the Hertzian waves appear to have unchained and which will not even be taken into account by those who by their strict duty have only Right and Justice to consider, assisted by a modest but conscientious examination of the opposing submissions and the documents put in evidence:

Whereas these documents have enabled us to reject both the accusation of plagiarism, and the claim of forfeiture [fol. 2320] for failure to work within the legal time limit, which were brought against the patent set up and have further enabled us to investigate clearly the remarkable nature of the apparatus seized at Marseilles and Havre against the Société Radiotélégraphique and the Société Radioélectrique, both of whom are well qualified to look ahead instead of wasting time in reargued actions, and thus to substitute for proceedings which have given rise to complaint, but which are excusable on account of the subtlety of the problems raised, the fruitful victories which doubtless await them upon new paths and in regions that were unsuspected yesterday, but which are now beginning to deliver up their mysteries:

Whereas, however, the documents put in during the arguments by the Marconi Company do not supply any means whereby the damage for which they claim compensation can be ascertained; whereas the small value of the seizures made by them show how insignificant had been up to then the actions of the Defendants; whereas under these circumstances and specially with regard to the position of the pleading, the Court is compelled to order that this damage shall be ascertained by reference, recommending the referee to operate in such a manner as to avoid everything that may appear like a roving commission over the affairs of the two Companies- rivals of the Plaintiff Company, younger than the latter, but, perhaps, as deserving as the Plaintiffs and as desirous to serve the interests of science and the good of the public; whereas the referee must also bear in mind the theories which are put forward on both sides and which the high authority of the Counsel for parties has been able,

by considerable effort, to set forth clearly, and which makes the action of the Defendants very excusable:

For these reasons the Court—

In due form, having regard to the connection in the subject matter, consolidates the actions in order to comprise the whole under the same judgment:

Gives to Legru a record that he leaves the matter in the hands of the Court to decide as to the question of infringement:

As to the Substance:

Gives to the Société Générale de Transports Maritimes à Vapeur a record that they reserve their right to claim upon the Compagnie Générale Radiotélégraphique in the event of their working being interfered with by the substitution of the confiscated apparatus:

Holds that the Marconi Wireless Telegraphy Company are properly entitled to the patent granted on the 3rd November, 1900, with regard to improvements in wireless telegraphy; that the same is valid, as it produces an industrial result which is new beyond question:

Holds that the patent has been worked in France within the legal limit both by manufacturing the appliances and by installing them in a series of wireless telegraphy stations:

[fol. 2321] Holds that the electrical installations and apparatus seized at Marseilles from the Société Générale Maritime and the Compagnie Générale Radiotélégraphique, then at Havre from Legru and la Société Française Radio-électrique are infringements of the Marconi patent:

Restrains the Compagnie Général Radiotélégraphique and the Société Française Radioélectrique from constructing, exhibiting, installing and offering for sale appliances which constitute an infringement of the said patent:

Orders the confiscation of the apparatus seized both as regards the two Companies and the Société Générale Maritime de Transports à Vapeur and Legru:

Jointly and severally awards against the Compagnie Générale Radiotélégraphique and the Société Générale Maritime de Transports à Vapeur on the one hand and the Société Française Radioélectrique on the other, an amount of damages to be fixed by a Referee and which will comprise in addition to the claim in respect of acts committed previous to the commencement of the action, all acts of infringement committed since that time:

Appoints, in order to carry out this order, Arnitz as Referee, duly sworn, unless he should be excused from doing so by the parties;

Orders the insertion by extracts of the present Judgment in five papers published in Paris and ten published in the provinces, at the choice of the Plaintiffs, provided that the cost of each insertion shall not exceed 500 francs for the first named and 200 francs for the latter;

Orders the Defendants in the Lower Court jointly and severally to pay the costs in that action and the Defendants in the Higher Court to pay the costs in same, all which costs are to be paid to Me. Haquin in legal tender.

Orders the Société Radiotélégraphique to guarantee and indemnify the Société Générale de Transports Maritimes à Vapeur in respect of the above Judgment given against them in favour of Marconi's Wireless Telegraph Company, Limited, and at their expense to instal fresh apparatus fulfilling the conditions laid down at the time the seized apparatus were fitted up;

Orders the Société Française Radioélectrique to reimburse to Legru the cost of the confiscated apparatus in respect of their value, including expenses of installation, to be settled by Arnitz, designated and appointed as above, and who, as far as required, for this further reference will be Sworn unless the oath is dispensed with by the parties.

Orders the Société Générale Radiotélégraphique to pay the cost of the special claim of Legru, with allowance of costs to Me. Brunet, Solicitor, in legal tender.

States that as far as requisite the legal expenses, double fees and fines which may result from the present Judgment shall be included in the costs to which they reasonably belong, and this, if need be, by way of damages. M. DAYRAS, [fol. 2322] substitute Mes. SELIGMANN, TRAVERS, TAILLEFER and SARRAUTE, Advocates.

NOTE. I. H. As to the two first points, the Judgment recorded applies a principle that is constantly maintained in doctrine and jurisprudence to a particularly interesting invention, viz., that there is a patentable invention in the new combination of known means or elements resulting in a new industrial result or presenting new advantages. *Vide* especially Cass. 4 May, 1901 (Gaz. Pal. 1902, 2315); 23rd June, 1905 (Gaz. Pal. 1905, 2141); and the notes, and among more recent decisions which have also applied this principle: Trib. civ. Seine 27th June, 1911 (Gaz. Pal. 1911, 250);

12th July, 1911 (Gaz. Pal. 1911. 2.79) ; with the notes and references to decided cases and authors. *Vide* likewise the cases quoted in Gaz. Pal. 1912. 1, Table, reverse side, letters patent No. 15. Adde Pouillet, Taillefer and Claro; Letters patent No. 46.

III. On the third point: Usurpation of the essential idea of a patented process constitutes infringement, in spite of differences in detail; Cass, 16th January, 1912. 2. Degrees. (Gaz. Pal. 1912. 1.413); Paris, 11th May, 1904 (Gaz. Pal. 1904. 1. 762); 6th March, 1899 (D. 1904. 2. 317); Trib. Civ. Seine, 26th March, 1912 (Law of 4th April, 1912—Gaz. Pal. 1912. 1, reverse side, letters patent No. 31); Trib. Civ. Lyons, 9th February, 1912 (Law of 24th January, 1912—Gaz. Pal. *loc et verb. cit.*, No. 28).

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В у г о л ы

Go for Account of Advances

L. 112 BRADSHAW, EST. 1871.

New York

NEW YORK, N. Y., \_\_\_\_\_, 19\_\_\_\_.

1. I, 2.3, for the first part of the Seventeenth of the Navy party of the second part, Witnesseth, That

I, 2.3, on behalf of 1.1, acknowledges hereinafter specified, the party of the first part,

I, 1.1, myself and its personal and legal representa

4.22. The next example is a graph with 12 vertices and 20 edges. The vertices are arranged in a circle, and the edges are as follows:  $v_1v_2, v_2v_3, v_3v_4, v_4v_5, v_5v_6, v_6v_7, v_7v_8, v_8v_9, v_9v_{10}, v_{10}v_{11}, v_{11}v_{12}, v_{12}v_1, v_1v_4, v_2v_5, v_3v_6, v_4v_7, v_5v_8, v_6v_9, v_7v_{10}, v_8v_{11}, v_9v_{12}, v_{10}v_3, v_{11}v_6, v_{12}v_9$ .

1. The purpose of the report will furnish and develop the  
2. The report will be in the form of a narrative and will be  
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...ANT'S ... specified days from the date of the ...

Requisition No. 82. Bureau. Naval Supply Account

Item No.

- (1) 1 2-K.W. wireless telegraph set, complete, variometer type, motor generator to be wound for 125 volts, D.C.
- (2) 1 1-K.W. wireless telegraph set, complete, commercial type, motor generator to be wound for 125 volts
- (3) 1 1-K.W. wireless telegraph set, complete, commercial type, motor generator to be wound for 125 volts D.C.

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---ELIVEY---

Items 1 and 3 to be delivered to Gen'l. Storekeeper Navy Yard,  
B'klyn, N.Y.

Item 2: 100 of 1000000 to Gen'l. Storekeeper, Navy Yard,  
Capt. Boutwell.

EACH WIRELESS TELEGRAPH SET TO CONSIST OF THE PARTS NAMED IN THE LIST BELOW GIVEN:

ITEM NO. 1.

This set will consist of the following:

Complete transmitter (Primary and Secondary Variometers, Spark Gap and Paper Condenser in Peak Case), New Horizontal or C.B.V.B. type Receiver with two Detectors and three Telephones, Key, Transformer, Aerial Hot Wire Ammeter, Aerial Switch, Switchboard, Hand Starter, Motor Generator (with spares required by 1675), and high frequency Protector Board.

DELIVERY:-----FIFTEEN DAYS (15), EXCEPT RECEIVER, WHICH IS TO BE DELIVERED WITHIN NINETY (90) DAYS.

ITEM NO. 2.

This set will consist of the following:

Transmitter (Spark Gap, Condenser, Transmitting Spiral and Aerial Hot Wire Ammeter), new special horizontal type Receiver with two Detectors and one Telephone, Key, Transformer, Aerial Switch, Switchboard, Hand Starter, Motor Generator with five spare sets of Brushes for motor and high frequency Protector Board.

DELIVERY:-----FIFTEEN (15) DAYS, EXCEPT RECEIVER,

WHICH IS TO BE DELIVERED WITHIN NINETY DAYS.

ITEM NO. 3.

This set will consist of the following:

Transmitter (Spark Gap, Condenser, Transmitting Spiral and Aerial Hot Wire Ammeter), new special horizontal type Receiver with two Detectors and one Telephone, Key, Transformer, Aerial Switch, Switchboard, Hand Starter, Motor Generator with five spare sets of brushes for motor and high frequency Protector Board.

DELIVERY:-----FIFTEEN (15) DAYS, EXCEPT RECEIVER, WHICH IS TO BE DELIVERED WITHIN NINETY (90) DAYS.

One complete set of spare Leyden Jars to be furnished for each of the sets under items 2 and 3.

The switchboard should have the following:

- 1 A. C. Voltmeter,
- 1 A. C. Ammeter,
- 1 Frequency Meter,
- 1 Solenoid Switch,
- 2 Knife Switches,
- 2 Rheostats,
- Plugs,
- Key.

The switchboard equipment for these sets to include the following:

- 1 A. C. Voltmeter,
- 1 A. C. Ammeter,
- 1 Frequency Meter,
- 1 Solenoid Switch,
- 1 Starting Switch,
- 2 Knife Switches,
- 2 Rheostats,
- Plugs,
- Key.

(2)

If the sets are furnished with hand starters, no starting switch is required.

Copper coated jars to be furnished under item No. 3.

All RECEIVERS under this contract TO BE DELIVERED at the  
Navy Yard, Brooklyn, N. Y., and ONE at the Navy Yard, Portsmouth,  
N. H.

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August 22nd, 1912. ✓

The Sets covered by our bid are NOT in accordance with Specification 1675, Except Paragraph 108-113-114-115 and 116 and we are unable to comply strictly with the other paragraphs of Specification 1675 <sup>without</sup> seriously impairing not only the usefulness, but also the efficiency of the set as a whole.

All spare parts as required under Paragraphs 14a, 16e(12), 26b, 32k, 37d, 55e, 66j, 70b, 100a, and 117 are included except spare parts for the generators under Paragraph 100a, because the machine we use is an Inductor Alternator with stationary Field and armature windings. As no battery is required with our Detectors, no spare primary batteries as for Paragraph 30 are supplied.

The Sets we propose supplying are of our Standard 500 Cycle Quenched Spark System and of <sup>our</sup> latest Switchboard type in which the Spark Gap, Transmitting Spiral and Relay Key and the Aerial Coils, Aerial Variometer, Aerial Hot Wire Ammeter, Aerial Capacity and connections are mounted on Metal frames similar to switchboard panels and are intended to be set up in a similar manner, i.e., simply attached to the wall and floor. They are NOT of the Variometer type but have a range of from 500 to 2000 meters and can be rapidly set for any of five (5) steps within this range as, for instance, 600, 900, 1200, 1600, or 2000 meters.

The transmitting condensers are made up of standard 20 microfarad glass jars in an aluminum porcelain insulated

August 22nd, 1912.

rack. The Leyden Jars we propose supplying will be of our usual high quality and in accordance with Paragraph 16 except e3-e3-e4-and e10 which requirements we consider entirely unnecessary if not impracticable and tending in no way to effect the operation on the durability of the sets.

The Switchboards we propose supplying will be of the simplified type as shown in our attached blueprint No. 200 same as supplied by us on all recent orders.

The Receivers we propose supplying with each set will be as follows:-

- (a) Our Standard Upright Type E5 Receiver with a range up to 10000 meters and with interchangeable variable primary and interchangeable variable secondary coils and variable primary and variable secondary condensers with the primary capacity so arranged that it can be connected up with the antenna either in series or parallel by means of a switch.
- (b) Same as under (a) but with a range of from 300 to 3000 meters.
- (c) Our Standard Horizontal Type E4 Receiver with a range of from 300 to 3000 meters and with a variable primary and variable secondary coil and a variable primary condenser arranged so that it can be connected either in series or parallel with the antenna by means of a switch.

The Detectors we propose supplying will be of our latest form of Iron Pyrites Detectors covered by U.S. Patent dated Sept. 12th, 1911 and will be mounted on separate stands.

The Transmitters we propose supplying are of our H.T. or station type as shown in attached photograph No. 474 with a range of from about 200 to 3000 meters. Covered by U.S. Patent No. 1,000,000.

Each set will consist of the following:-

if it is as per the above is sufficient

August 22nd, 1912. ✓

of apparatus:-

One Motor-Generator.  
One Automatic Starter.  
One Switchboard with:

One Frequency Meter (Weston).  
One A.C. Ammeter "  
One A.C. Voltmeter "  
One Lampbracket.  
Two Fused D.P. Knife Switches.  
Two Rheostats.  
One Solenoid.  
One Set Terminals  
Instrument Fuses.

One Transformer.  
One Primary Choke Coil.  
One Key with Platinum Contacts.  
One Transmitter with Iron Frame, including:

Spark-gap with cover and ventilator.  
Transmitting Spiral with plugs and cords.  
Relay Key.

One Leyden Jar Transmitting Capacity in an  
aluminum porcelain insulated case.  
One Set Aerial Coils and Aerial Variometer in  
iron frame with connections, aerial capacity  
and Aerial Hot Wire Ammeter.  
One Lightning Switch.  
One set of Protective Appliances as per Paragraph 117.  
Three Receivers as described above.  
Three Detector Stands each for and including two  
Detectors.  
Three Double Head Telephones.  
One Tone Controller or Tone Tester with detector  
and cord.  
One KLI Tapermeter as described above with:

Variable Tone Buzzer.  
One Lamp.  
One Helium Tube.

One Set of Spares consisting of:-  
One Motor Armature.  
One " Field Coil.  
One Set Brushholders.  
One " Brushholder - rings.  
Ten Sets Brushes.  
Ten Set of all fuses in switchboard.  
One set spare Cords.

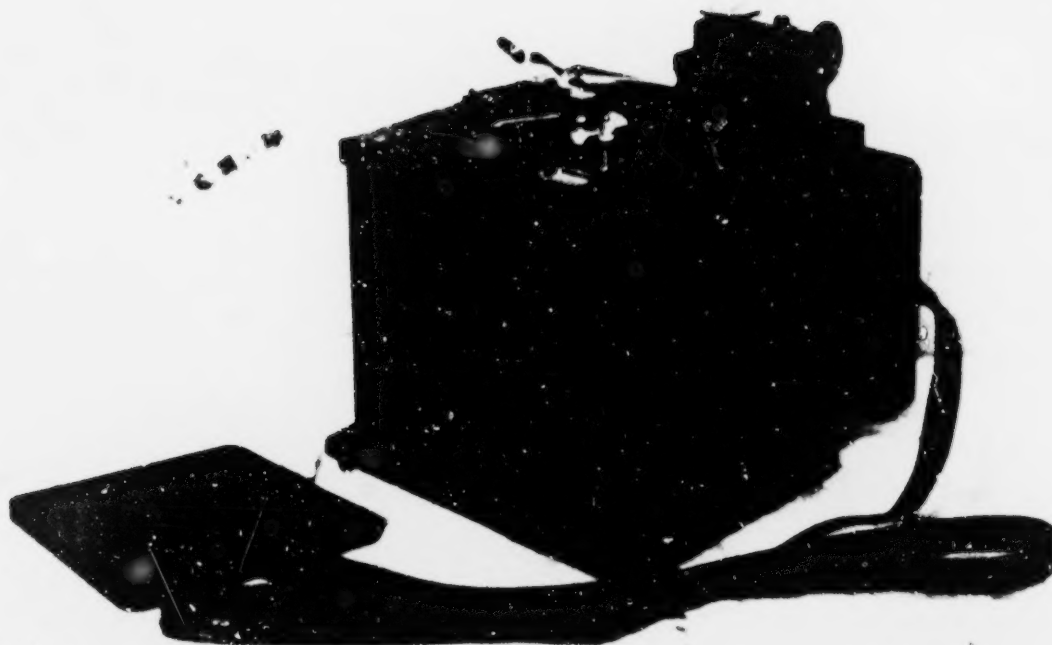
2700  
-4  
THE FUNKEN WIRELESS TELEGRAPH COMPANY OF THE UNITED STATES

August 22nd, 1912. ✓

Two Double Head Telephones.  
Fifteen Telephone Cords.  
Six Extra Cups with Crystals for Detectors.  
Four Spare Condensers for Detectors.  
Forty Spare Fuses for "  
Three Helium Tubes for Javemeter.

THE TELEPHONE AND TELEGRAPH COMPANY OF THE UNITED STATES

Richard Pfund  
Chicago



13 2 10  
NO 474

2701

U. S. NAVY PAY OFFICE  
NEW YORK

*Deliveries Co.*

Please return this proposal in duplicate, duly signed, by 12 o'clock noon, AUG 16 1912, with price stated opposite each item named below, for delivery, free of charge, at specified place, within \_\_\_\_\_ days from receipt of order subject to the conditions printed on the back of this form.

Respectfully,  
which to be considered must show unit price, estimation, and total amount of bid.

NAVY PROPOSED  
U. S. NAVY  
Wm. JACKSON & COMPANY  
Purchasing Agent, U. S. A.

ARTICLES REQUIRED.	Price of Item		Total	
	Quantity	Unit Price	Quantity	Unit Price
Requisition No. 59 Ea. Naval Supply Account. Item No.				

(1) Two (2) S. K. S. 800 cycle, motor pump, motor, reversed gear, radio telegraph sets; complete with spare parts

To be in accordance with specifications 14-7-8, issued by Navy Dept., except as modified hereby. Bids to be made strictly in accordance with paragraph 11a, specifications 14-7-8, and paragraph 11a (c) will be strictly enforced.  
Bids as per paragraph 11a d are subject to special approval in each case, and, unless approved, the contractor will be required to meet the corresponding specifications, 14-7-8, when the apparatus is required for final acceptance.  
All bidders must strictly comply with the following paragraphs of the specifications, 14-7-8, which are not to be made subject to modification by the bidders:-

- Paragraph 10a-Drawings, etc.
- 11a-Tests after delivery.
- 11b-Interchangeability.
- 11c-Instructions and misdirections.
- Spare parts

- 14-a-For ventilation of spark gap.
- 14-b-17 For condensers of transmitter.
- 14-c For all anodes of detector.
- 14-d-For primary batteries.
- 14-e-For telephone cords.
- 14-f-11 For wave meter ballium tubes.
- 14-g For circuit breaker contacts.
- 14-h For panel fuse.
- 14-i-11 do
- 14-j-11 For motor and dynamo.
- 14-k For protection appliances.

Special consideration will be given bids offering apparatus in which the transmitting wave length can be continuously and readily changed, as per paragraph 6c of the specifications, over a range from 500 to 1000 meters; also for compact apparatus in accordance with paragraph 6a of the specifications.  
The ballium condensers made up of Standard Leyden Jars will be required.

Three (3) receivers to be furnished with each set, as follows:

- (a) One highly selective receiver of special design for receiving wave lengths up to 10,000 meters, to be furnished with a variable condenser in primary circuit with leads which can be operated by switches to put this condenser in service or in parallel with inductance or to cut it out.
- (b) One highly selective receiver with variable condenser, for primary circuit as required for (a), for receiving waves from 500 to 5,000 meters for ship communication.
- (c) One simplified receiver, range 500 to 5,000 meters, to consist of variable primary inductance, variable secondary, with means for varying the mutual inductance between the two circuits, and variable series condenser.

All detectors must be fitted with binding posts for 6 detector mounted as a separate item. Detectors, suitably mounted, as specified will be accepted.  
Bidders will describe particularly receivers and detectors they propose to furnish.

One (1) wave meter will be required with each set.

DELIVERED at the Navy Yard, New York, for inspection and acceptance within the shortest possible time, and to be a perfect in every respect.

22, 24 DELIVERED to the Central Storehouse, New York.

2-6

②

### ADDITIONAL ANSWERS OF TEST 4

11 3 20 00

We - do hereby agree to furnish within thirty (30) days and in conformity with this proposal  
 the above articles at the prices affixed thereto, and if the amount of the proposal exceeds five hundred dollars, within five  
 days after receipt of notice of its acceptance, to enter into contract in accordance with the general conditions printed  
 herein to furnish and deliver the articles as stated. In event of our failure to make delivery within the time  
 specified, or to execute the contract as agreed, the order to be placed elsewhere, and any difference in price charged  
 to our account.  
 (My name)

Signature of a competent, reliable person  
and an address of a place in England

44-38861-10

1.4.3. *Results*

Richard A. Pines, Inc.  
111 Broadway

111 Howard St. New York, N.Y.

10/10/54

Dear Sir:

Enclosed for the Postmaster General are 100 copies of the "Report of the Commission on the Administration of the Federal Bureau of Investigation" for the year 1953. The report is being distributed to all members of the House of Representatives and the Senate, and to all members of the Executive, Legislative, and Judicial Branches of the Government. It is also being distributed to all members of the press and to all members of the public who have requested it. The report is being distributed to all members of the House of Representatives and the Senate, and to all members of the Executive, Legislative, and Judicial Branches of the Government. It is also being distributed to all members of the press and to all members of the public who have requested it.

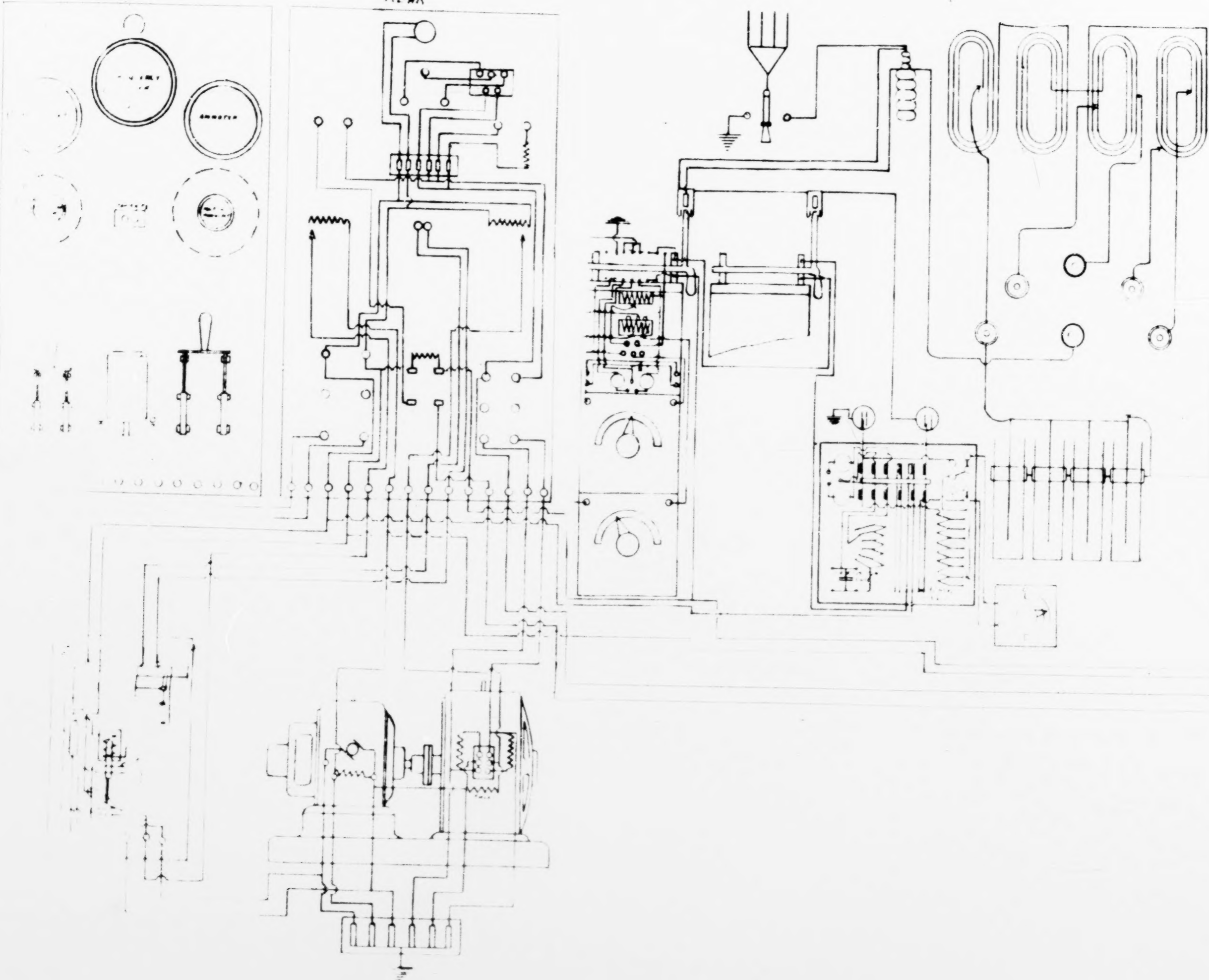
Sincerely,  
 J. Edgar Hoover

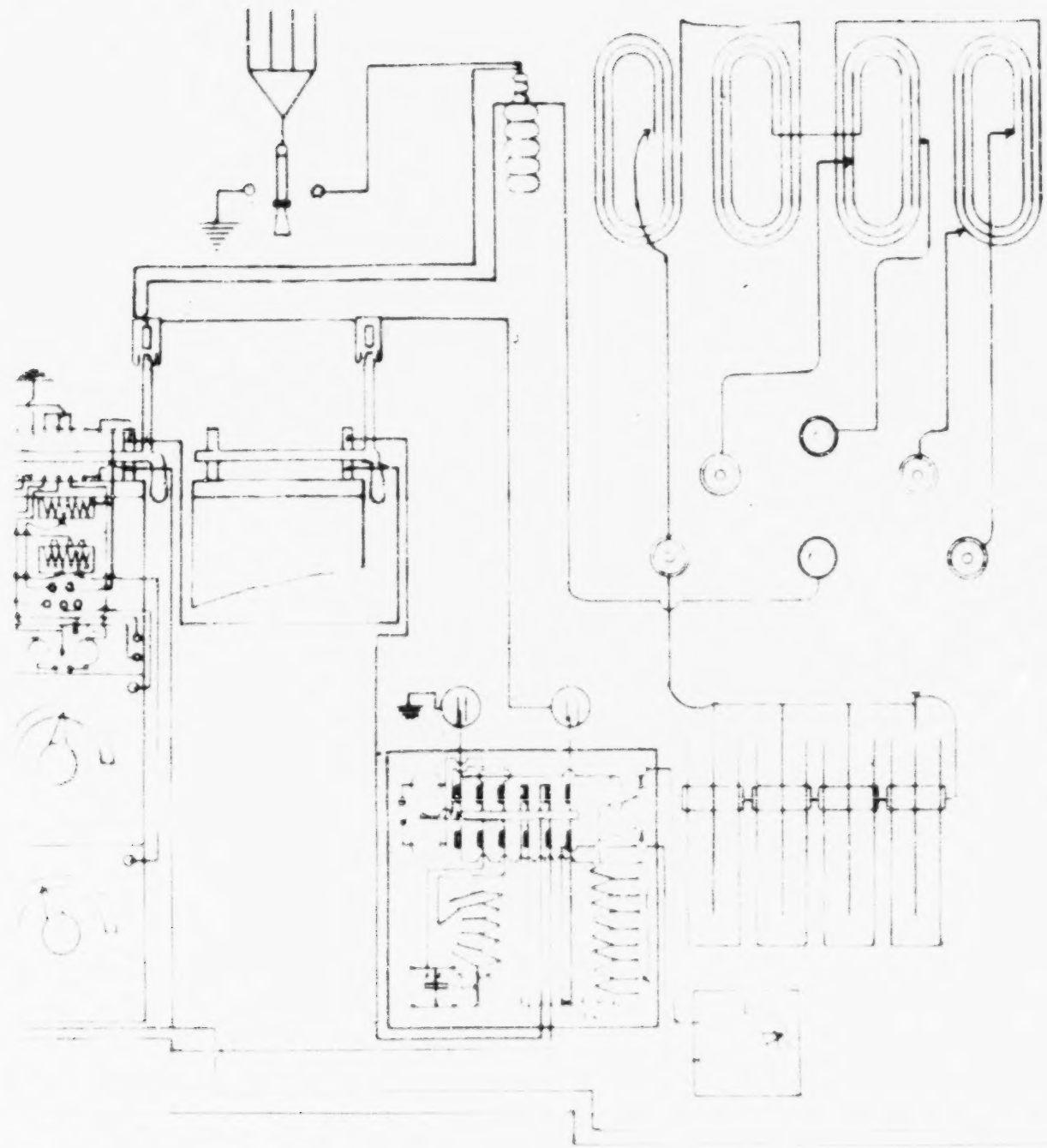
Enclosure

All Turkish affairs in Article except 10, are in Section.  
 Questions relating to the republic be 30 on the

FRONT

REAR





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# PLAINTIFF'S EXHIBIT 53

D-1

2707

DEPARTMENT OF THE INTERIOR	
OFFICE OF THE COMMISSIONER	
RECEIVED	1910
NOV 10	1910
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Signal Corps, United States Army.

These Articles of Agreement entered into this twenty-seventh day of

June, between C. DeF. Chandler, Captain, Signal Corps, United States Army, of the first part, and Foots, Pierson & Company, a partnership composed of George L. Foots and Henry G. Pierson, with an office at 100 Duane Street.

of the county of New York, State of New York, of the second part. Witnesseth, that in conformity with copy of the advertisement, specifications, and proposed terms attached, and which, in so far as they relate to this contract, form a part of it, the C. DeF. Chandler, Captain, Signal Corps, United States Army, for and in behalf of the United States of America, and the said FOOTS, PIERSON & COMPANY,

hereinafter designated as the contractor, do covenant and agree, to and with each other, as follows, viz:

Article I. That the said contractor shall manufacture for and deliver to the United States of America, the following:

IGHT (8) Field wireless peak sets, complete with storage batteries, in accordance with Signal Corps specifications No. 410, part "B," revised, and complete set furnished the contractor. (Sets to be serially numbered in accordance with instructions contained in the order.)

ORD N No. 8908, copy attached hereto, forms a part of this agreement.

Article II. That the deliveries of the supplies and materials herein contracted for shall be made in the manner, numbers, or quantities, and for each number or quantity, on or before the date specified therein as follows: delivery

That complete shall be made on or before OCTOBER 25, 1910.

Article III. All supplies and materials furnished and work done under this contract shall, before being accepted by the Government, be inspected by an inspector appointed on the part of the Government.

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and such as do not conform to the specifications set forth in this contract shall be rejected. The delivery of the Chief Signal Officer, United States Army, as to quality and quantity shall be final.

Art. IV. That for and in consideration of the faithful performance of the stipulations of this contract, the contractor shall be paid at the office of ~~the Chief Signal Officer~~ of the Army at Washington, D.C. for all supplies and materials delivered in conformity with the requirements of this contract, on or before the date above specified (Article II, *supra*) and accepted, the following prices, viz:

EIGHT <sup>(8)</sup> ~~8~~ Wireless pack sets, at three hundred and seventy-four (374) dollars each, making a total consideration of two thousand nine hundred and thirty-two (2,932) dollars.

to be paid as soon as practicable after the acceptance of the same, in funds furnished by the United States for the purpose, reserving    per cent from each payment until final settlement, on completion of the contract or otherwise.

Art. V. It is further agreed that for all supplies and materials which shall not be delivered in conformity with the requirements of this contract on or before the date prescribed therefor in Article II, above, but which shall be subsequently delivered and accepted, the prices shall be as follows:

NOTICE: Inspectors cannot accept departures from this specification. Indicate exceptions with your bid

SIGNAL

JUN 9 1919

## GENERAL SPECIFICATION, NO. 410. (March 20, 1909).

### WIRELESS TELEGRAPH EQUIPMENT, OF

#### INTRODUCTORY.

This specification covers all of the equipment necessary for the operation of a portable wireless telegraph outfit. The equipment specified herein may be made in its entirety or by unit parts in the discretion of the Chief Signal Officer of the Army.

If the order is placed for the equipment in its entirety under this specification, the contractor will be held accountable for the efficiency and proper operation of the unit parts, the inspection covering the completed outfit.

A contractor will not be held accountable for the efficiency of the outfit under any condition, but will take great care to see that every detail of specification is followed out in the construction of the apparatus covered

This specification is intended for the information of the manufacturer only and is not a description of the installation or operation of the equipment.

This specification is divided into five parts as follows:

- Part A - General Requirements.
- Part B - Antennae.
- Part C - Generating Set.
- Part D - Receiving Set.
- Part E - Combined Generating Set.

This specification will be issued in its entirety only when bids are asked for the parts mentioned herein.

#### TABLE OF SPECIFICATIONS.

Antennae	96
Receiving Apparatus	221
Transmitting Apparatus	368
Combined Apparatus	403
Receiving and Transmitting	416
Antennae and Receiving	430

#### INSTRUCTIONS.

The contractor must furnish the parts of this specification, and when considered complete, be furnished the contractor with the F M of this specification and the articles to be supplied.

- Part A - Drawings.
- Part B - Fold Set, pack, wing kite..... 534a
- Wire reel
- For kite..... 504b
- Fold wireless set, pack, hollow
- sectional mast with controls
- terminal and counter size wires..... 649a
- Wireless set, pack, hollow
- sectional mast, set, hollow..... 649b
- Part C - Combined set, pack, generating
- set, hollow..... 490a
- Fold wireless set, pack, generating
- set, hollow..... 490b
- Fold wireless set, pack, generating
- set, hollow..... 490c
- Wireless set, pack, generating
- set, hollow..... 490d
- Wireless set, pack, generating
- set, hollow..... 490e

NOTICE: Inspectors cannot accept departures from this specification. Indicate exceptions with your

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U. S. P. 414—2

Field wireless set, pack, generating set circuit breaker.....	490h
Field wireless set, pack, generating set, battery and spark coil for for.....	499i
Field wireless set, pack, generating set, cover.....	500j
Field wireless set, pack, generating set, circuits.....	507b
Part V - Standard binding posts..... 510	
Field wireless set, pack, cabinet, tuning coil.....	497a
Field wireless set, pack, interrupter.....	549
Field wireless set, pack, induction coil, for.....	550r
Field wireless set, pack, induction coil, details.....	555r
Field wireless set, pack, open spark gap.....	556
Field wireless set, pack, sending key.....	560
Field wireless set, pack, terminals for Leyden tube condenser.....	562
Field wireless set, pack, terminals.....	563
Field wireless set, pack, trunk type, wiring diagram.....	564
Field wireless set, pack, tell-tale, lamp mounting.....	563i
Field wireless set, pack, linking spiral.....	564
Field wireless set, pack, double throw control switch.....	567
Field wireless set, pack, Leyden tube.....	568
Primary condenser, 2 m. f. for trunk set wireless.....	568
Part VI - Packing box for hand generator, field wireless, set pack..... 567b	



A-13

2712

# 1. GENERAL REQUIREMENTS--- (2)

(d) Brass: Sheet brass shall be what is commonly known as low brass and shall have a composition approximately as follows:

Copper ---80%  
Zinc---20%

Brass for binding posts, etc. shall have approximately the following composition:

Copper---67  
Zinc-----33%

(e) Hard Rubber: The hard rubber covered by this specification shall be of the best grade obtainable made up from best Para rubber and sulphur with no other ingredients. Samples will be subjected to chemical and mechanical tests.

(f) Fibre: The fibre covered by this specification shall be red in color and so treated as to be impervious to moisture. Samples shall be subjected to test for mechanical strength and hygroscopic qualities.

(g) Slate: All slate specified herein shall be of the best grade (Anson) oil finished sand black. The rear of the slate will also be thoroughly oiled.

(h) Marble: All marble shall be white Italian, free from all flaws whatsoever.

(a) Brass work will be in four standard finishes, as indicated hereinafter. The finishes will be designated as follows:

- Standard dark finish.
- Standard nickel finish.
- Standard telegraph finish.
- Dip lacquered.

All brass work will be finished in one of these styles.

(b) The standard dark finish for brass work not a contact surface will be obtained by the use of either of the following methods:

1. By the use of a solution of arsenic made by dissolving common white arsenic, arsenious oxide, in hydrochloric acid.
2. Copperplate the part to be finished, then using an alkaline polysulphide solution such as sodium polysulphide.

Care must be taken in the preparation of the parts to be finished to see that they are entirely free from lacquer or grease. Clean lacquer will be applied to the parts after the desired finish with the above solutions has been secured.

(c) The nickel finish will conform to the requirements of Part 2.

(d) The standard telegraph finish will conform to that of the best grade telegraph instruments, being polished and lacquered.

(e) Brass parts not ordinarily exposed will be dip-lacquered. Care being taken that all parts are thoroughly cleaned before lacquering.

(f) The standard finish for copper parts not forming contact surfaces will be obtained by dipping into a solution of alkaline polysulphide, such as sodium polysulphide. Care will be taken to see that the parts to be finished are free from grease or lacquer before dipping in the solution and clear lacquer will be applied to the parts after the desired finish is obtained.

(g) The standard finish for all woodwork is as indicated below. This finish will be accurately followed for all wooden parts of this equipment.

The following applies only to specification No. 410 - Field Wireless Set, when "all woodwork and interior of pack chest shall be finished in the following manner:

Stained light mahogany and rubbed down after being dried for twelve hours. Three coats of varnish shall then be applied. The woodwork shall be rubbed down after each operation with pumice stone and crude oil. The finish when complete shall be smooth but not glossy, and shall present no evidence of open pores in the wood, and shall not be easily scratched or marred."

The following applies to Specifications

- No. 404-Standard Marine Wireless Telegraph Equipment.
- 479-Station Wireless Equipment, 10 k.w.
- 485-Wireless Telegraph Equipment, 1 k.w. station set.
- 516-Wireless Equipment "Joseph Henry."
- 518-Station Wireless Telegraph Set, 5 k.w.

Woodwork shall be finished as follows:

Wiped with medium grade "Solv" oil, and after being rubbed down

AT-14

## PART A GENERAL REQUIREMENTS -- (S)

hours shall be covered with a coat of orange shellac. After being rubbed smooth with sand paper, a coat of rubbing varnish shall be applied and rubbed down with pumice stone and grade oil. The woodwork shall receive two coats of rubbing varnish and shall be rubbed down after each operation. The finish when complete shall be smooth but not glossy, and shall present no evidence of open pores in the wood, and shall not be easily scratched or marred."

The successful bidder will decide upon the color and the quality of the finish from the sample which will be supplied him.

(b) Hard rubber, where exposed, will invariably be polished.

(1) Ironwork will be galvanized to meet the requirements of specification No. 96

#### 5-PROPERTY NUMBERS:

The property numbers shall be serial and shall accompany the order. If these numbers are not indicated in the order the manufacturer shall take care to put them and see that they are on the instruments before inspection.

#### 6-METAL WORK:

All metal work shall be provided with a rustless coating of one of the types specified above and it shall meet the test indicated above.

If not otherwise specified, the metal parts, unless magnetic qualities require otherwise, shall be made of brass. All threads and screws shall be U. S. commercial standard.

#### 7-NAME PLATES:

(a) The name plates shall be of brass and shall conform to the drawings of the several instruments.

(b) These plates will in all cases be machine-engraved.

(c) These plates will be ordered in one of two finishes as follows:

Standard dark finish,  
Nickel grain finish.

(4) The standard dark finish will be obtained as indicated in Paragraph 4-b and the letters will be filled with white enamel.

(e) The nickel grain finish shall conform to Signal Corps standard and letters shall be black-filled. Sample will be furnished the manufacturer.

#### 8-PACKING:

All articles described herein must be packed with great care. The packing will be made the subject of inspection and if crates are not satisfactory to the inspector, the materials will not be accepted until proper package is provided.



U. S. N. 110—PART D—2

- (c) The insulation between the primary and secondary windings shall withstand the application of an alternating current of 40,000 volts for 10 seconds.
- The primary winding shall withstand the application of 50 volts alternating current for a period of one minute.
- (d) The outside containing case shall receive two coats of heavy transparent enamel with rubber finish. The top side of the case shall have stamped in the metal, in letters not less than 1/4" high, the following words:  
INDUCTION COIL  
U. S. SIGNAL CORPS.



INTERRUPTER:

- The interrupter furnished under this specification shall conform generally to dimensions given in drawing 549 and meet the following requirements:
- (a) Material: All materials used must be the best of their kind.
- (b) Workmanship: Every part of the work on this interrupter must conform to the highest grade of workmanship.
- (c) The base shall be hard rubber polished on all exposed surfaces.
- (d) Fittings: Fittings on exposed surfaces shall be provided with gray nickel finish and where not forming a part of the magnetic circuit or not in direct contact with the air, shall be of brass.
- (e) Windings: The magnet shall be wound with No. 34 B. & S. gauge single cotton covered copper magnet wire and shall be thoroughly water-proofed. Magnet leads shall be fibre and a fibre shell shall be interposed between the magnet windings and the core. Windings shall each have a resistance of about 9 ohms. The shell of the bobbins shall be covered with pebble cloth.
- (f) Magnetic circuit: Care shall be taken to make accurate joints in all parts of the magnetic circuit. This will receive special attention at inspection.
- (g) Insulation: All materials for insulation, including milled heads for adjusting screws, insulation for bassor contacts, and the base shall be of the best grade of hard rubber.
- (h) Contacts: Contacts shall be of platinum and shall be fully equal to dimensions shown on drawing.
- (i) Contact springs: Particular care must be taken in the selection of the contact springs in order that rigidity and certainty of action of the interrupter may be secured. It may be necessary to make several changes before a satisfactory spring is obtained and the contractor will be required to satisfy the inspector in this particular. The dimensions shown in drawings are furnished as a guide, the complete interrupter must equal sample in operation.
- (j) Tests: Inspections will particularly include the efficiency of the springs, accuracy of the contacts, insulation of windings and contacts, accuracy of fit of the adjusting screws, general appearance of the completed interrupter as well as such other tests as the inspector may deem necessary.

SENDING KEY:

- The key shall be standard open circuit key telegraph key provided with special platinum contacts as shown on drawing 540, and meeting the following requirements:
- (a) Base: The base shall be of brass or other approved non-corrosive metal.
- (b) Springs shall be of phosphor bronze.
- (c) Levers shall be made of phosphor bronze.
- (d) Transmissions shall be of blued steel or phosphor bronze.
- (e) Insulation: The switch knob, lever tip, and other insulation shall be of hard rubber.
- (f) All metal work shall have a standard case finish.
- (g) Markings: The letters U. S. S. C. shall be stamped on the base.

CONTROL SWITCH:

- (a) The control switch shall conform to drawing 572 in all details.
- (b) The control switch shall be made of the best like copy, or, if made of brass, shall be polished to dimensions.
- (c) All hard rubber used shall conform to General Requirements, Part A, of this specification.
- (d) The construction must conform in general to the requirements of specification No. 360, covering the main features of knife switches.

TUNING COIL:

- The tuning coil furnished under this specification shall conform to the dimensions given for the short coil of drawing 497c and meet the following requirements:

## SPEC. 410 -- Part 2--(3)

(c) Cylinders: Cylinders shall be of hard rubber per general requirements, Part 1, of this specification, and shall have a spiral groove with 24 pitch to accommodate winding.

(d) The cylinder shall be wound with No. 24 B. & S. gauge hard brass wire. After winding on the cylinder, this wire shall be heavily copper-plated and nickled. No hot solution shall be used in the plating process and particular care shall be taken to leave the completed cylinder entirely free from plating and cleansing solutions.

(e) Contactors and adjusting bars shall be made of brass, gray nickel finish.

(f) All other metal work shall be brass, polished, and heavily dip-lacquered.

## 11-SILICON DETECTOR:

This shall be the standard silicon detector as made by the Wireless Specialty Co., 41 New Street, New York, and shall be furnished with nickel-plated mounting, retaining chain for button, and fittings complete for connection to the wireless receiving set.

## 12-TERMINALS:

(a) The terminals shall conform to drawing 549.

(b) The lock nut binding posts shall conform to dimensions shown on drawing 549.

(c) All hard rubber used shall conform to General Requirements, Part 1, of this specification.

(d) Workmanship and finish must be first-class throughout.

## 13-TELETYPE LAMP:

(a) The teletype lamps shall be furnished complete with hard rubber mounting, as shown on drawing 631. Two spare incandescent lamps shall be furnished with each mounting ordered under this specification.

(b) All hard rubber shall conform to General Requirements, Part 1, of this specification.

(c) Binding posts shall be of brass, standard nickel finish.

## 14-LEYDEN TUBE CONDENSER:

This condenser shall be furnished complete with tubes and shall meet the following requirements:

(a) The Leyden tube terminals shall conform to drawing 566. One pair of terminals ordered shall comprise one set of upper terminals and one set of lower terminals as shown on the drawing.

(b) The spring clips shall be of the best grade of German silver. These shall be carefully formed to outline shown on drawing. Particular attention will be given to forming these spring clips so that the strength of the material will not be impaired in the process of forming.

(c) The base shall be made of hard rubber which shall meet the General Requirements, Part 1, of this specification.

(d) The Leyden tubes shall be designed for mounting on the terminals of drawing 566. They shall be the Telefunken make or equal. The dimensions shall be about 1 1/2 inch by one inch in diameter. The tubes shall be provided with copper strip protection as shown in drawing 566.

(e) The electrostatic capacity of these tubes shall be about .00075 K.F.

(f) Special care shall be taken by the manufacturer in packing the tubes ordered under this specification in order that the breakage in shipment may be reduced to the minimum. Two spare tubes shall be furnished with each condenser.

## 15-DOUBLE END RECEIVER:

This shall be the double end telephone receiver, H.V. Sullivan make, pattern A, with a resistance of about 3,460 ohms. It will be furnished with a five-foot twisted cord, silk covered. Three spare cords and six spare ear caps shall be furnished with each receiver.

## 16-TRUNKS:

The trunks shall be the Leatheroid Trunk Co's. standard make or equal and shall have dimensions of 21 inches long, 12 inches wide, and 12 inches deep, of which 2 1/4 inches shall be in the cover. The 21 inches by 12 inches inside surface of the cover and the bottom of the trunk shall be fitted with 3/8-inch lining of white pine or other hard wood. The inside dimensions above shall obtain after these linings are in place.

The trunk shall be thoroughly made up with one thickness of poplar between the cover and the body, the inside being lined with chamois-cloth.

The trunk shall be reinforced with leatheroid and corners shall have mild steel.

The trunk shall have an improved type of double hinged trunk lock with duplicate keys furnished.

The trunk shall have a rubber valance around to prevent moisture from entering the trunk.

A-18

... 1-inch side of the trunk.  
... there shall be secured by means of 1st head  
... 1-1/2 inches x 2-1/4 inches by 5-inches for  
...  
... olive drab paint made up according  
... white lead ground in raw linseed oil; one pint  
... quart raw linseed oil, one pound raw rubber.

... storage battery meeting the following re-  
... shall consist of two units of four cells each  
... six amperes charging rate, and shall be

... non-spillable, provided with vents, hard rubber screw  
...  
... carrying current shall have hard rubber covering.  
... polarity stamped on cover.  
... covered with rubber composition to resist

... unit, of four cells, shall not exceed 50 pounds.  
... shall be attached to front of containing case. This card  
... call directions for charging.

... shall have a total capacity  
... shall be the U. S. C. 8-4 or equal. Jars shall be of  
... thoroughly seasoned. Terminals shall be of brass as shown in  
... withstand a breakdown test of 500 volts D. C.  
... of 10 megohms.

... shall include the following parts in addition to those specified

... for connecting storage batteries to set and to each other and  
... to the trucks.

... at set of a 13 Lugger busser mounted on 2 14-0 dry cells.  
... inside of set for holding head receiver when set is

... for holding the spare parts supplied with the set.  
... 1st, spec. 166.

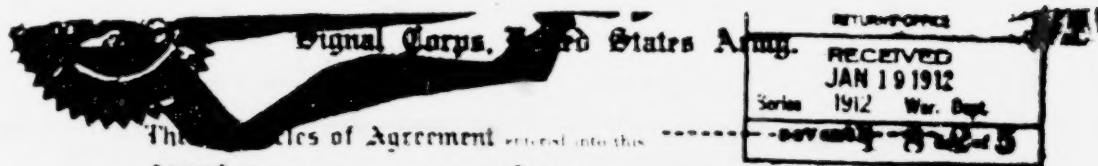
... dry switch.  
... for receiving a t.  
... for detector of 1200 ohms with top off for silicon of 30

... with the following:  
... ENT PART NO.  
... on both trucks.

JAMES MILBY,  
Brigadier General,  
Chief Signal Officer of the Army.

# PLAINTIFF'S EXHIBIT 59

2718



Signal Corps, United States Army.

RECEIVED	
JAN 19 1912	
Series	1912 War. Dept.
-seventy-8-2-5	

This **Order of Agreement** entered into this **December** **eleven**, between **R. J. Hurt**, **Captain**, **Signal Corps, United States Army**, of the first part, and **the Wireless Specialty Apparatus Company**, one of whose principal offices is at **No. 81 New Street, New York City**, in the county of **New York**, State of **New York**, of the second part, **Witnesseth**, that in conformity with copy of the advertisement, specifications, and proposal hereto attached, and which, in so far as they relate to this contract, form a part of it, the **R. J. Hurt, Captain**, **Signal Corps, United States Army**, for and in behalf of the United States of America, and the said **WIRELESS SPECIALTY APPARATUS COMPANY**, (hereinafter designated as the contractor) do covenant and agree, to and with each other, as follows, viz: **Article I. That the said contractor, shall manufacture for and deliver to the United States of America, the following:**

## ITEM:

1. **Two (2) sets, receiving, type 1-P-76, including telephone handsets, Wireless Specialty Apparatus Co. make.**

And It is further covenanted and agreed, that the deliveries of the supplies and materials herein contracted for shall be made in accordance with the quantities and for each number or quantity, on or before the date specified. **That complete delivery shall be made on or before January 17, 1912.**

Work done under this contract shall, before payment is made on the part of the Government,

ART. IV. That for and in consideration of the faithful performance of the stipulations of this contract, the contractor shall be paid at the office of ~~-----The Chief Signal Officer-----~~  
~~-----of the Army-----~~, at ~~-----Washington, D. C.-----~~, for all supplies  
 and materials delivered in conformity with the requirements of this contract, on or before the date  
 above specified (Article II, *supra*) and accepted, the following prices, viz:

**ITEM:**

1. Two (2) Receiving Sets, at three hundred twenty-five  
 dollars (\$325.00) each;

Making a total consideration of six hundred and fifty  
 dollars (\$650.00).

to be paid as soon as practicable after the acceptance of the same, in funds furnished by the United  
 States for the purpose, reserving ~~-----~~ per cent from each payment until final settlement, on completion  
 of the contract or otherwise.

ART. V. It is further agreed that for all supplies and materials which shall not be delivered in  
 conformity with the requirements of this contract on or before the dates prescribed therefor in Article II,  
 above, but which shall be subsequently delivered and accepted, the prices shall be as follows:

1111-1111's 1111-1111

Army Pay Office  
 - 1111-1111

Contract No. 133  
 Series 1913  
 Pay Office New York

( Acct. No. 09 Bu. A.S. Acct.  
 Account of ( Station 3 n r e a u  
 ( A. n. General Account of Advances

1111-1111, of the parts, made and concluded this  
 twenty-first day of September, A.D. 1911, by and between  
 Wireless Electricity Apparatus Co. of No. 61 New Street, New  
 York, in the State of New York, party of the first part,  
 and the said 1111-1111 of the Purchasing Pay Officer, United  
 States Army Pay Office, New York, N.Y., acting under the di-  
 rection of the Secretary of the Army, party of the second  
 part, of the State of New York, for and in consideration of the pay-  
 ments hereinafter specified, the party of the first part, for  
 itself and its personal and legal representatives, doth hereby  
 covenant and agree to and with the party of the second part,  
 as follows, viz:

1. That, it, the said party of the first part, will furnish  
 and deliver, at its own risk and expense, at such place in the  
 City of New York, Brooklyn, N.Y., as the Commandant thereof may direct,  
 and within specified days from the date of this contract, the  
 following articles, and at the price set opposite each item,  
 respectively:

acquisition no. by no. Naval Supply Account.  
Item No.

- (1) Two (2) 5 K.W. 500 cycle, motor  
ator, punched gap, radio telegraph sets,  
complete with spare parts

2721  
14-34  
\$5599.00 set

To be in accordance with specifications 16-1-5,  
issued by Navy Dept., except as modified hereby. Bids  
to be made strictly in accordance with paragraph 110,  
specifications, 16-1-5, and paragraph 118 (c) will be  
strictly enforced.

Modifications as per paragraph 118 d are subject to  
specific approval in each case, and, unless approved,  
the contract will be required to meet the correspond-  
ing details of specifications, 16-1-5, when the appar-  
atus is inspected for final acceptance.

All bidders must strictly comply with the following  
paragraphs of the specifications, 16-1-5, which are not  
to be made subject to modification by the bidders:-

- Paragraph 106-Drawings, etc.  
112-Tests after delivery.  
114-Patents.  
115-Interchangeability.  
116-Omissions and misdirections.

-----  
Spare parts  
-----

- 14-a-For ventilation of spark gap.  
16-B-12-For condensers of transmitter.  
28-b For electrodes of detector.  
30-For primary batteries.  
32-k-For telephone cords.  
37-d-12-For wave meter helix tubes  
56-e-For circuit breaker contacts.  
58-j-For panel fuses.  
70-b- do  
100-a-For motor and dynamo.  
117- For protection appliances.

Special consideration will be given bids offering apparatus  
in which the transmitting wave length can be continuously and  
rapidly changed, as per paragraph 4c of the specifications, over  
a range from 600 to 3000 meters; also for compact apparatus in  
accordance with paragraph 8a of the specifications.

Transmitting condensers made up of Standard Leyden Jars will  
be required.

Three (3) receivers to be furnished with each set, as follows:

- (a) One highly selective receiver of special design  
for receiving wave lengths up to 10,000 meters,  
to be furnished with a variable condenser in  
primary circuit with leads which can be oper-  
ated by switches to put this condenser in series  
or in parallel with inductance or to put it out.  
(b) One highly selective receiver with variable con-  
denser, for primary circuit as required for (a),  
for receiving waves from 500 to 3,000 meters for  
ship communication.  
(c) One simplified receiver, range 200 to 3,000 meters,  
to consist of variable primary inductance, vari-  
able secondary, with means for varying the mutual  
inductance between the two circuits, and variable  
series condenser.

All detectors must be fitted with binding posts for a detector  
mounted as a separate item. Detectors suitably mounted on receivers  
will be accepted.

Bidders will describe particularly receivers and detectors  
they propose to furnish.

One (1) wave meter will be required with each set.

DELIVERY at the Navy Yard, New York, for inspection and test  
within the shortest possible time, time to be a factor in award  
of contract.

TO BE DELIVERED to the General Storekeeper Navy Yard

ref - 34

Accepted for material in accordance with the specifications of requisition, except as modified in specifications (copy attached), blueprints, drawings, etc., submitted with bid:

Wireless Specialty Apparatus Co. proposes to furnish apparatus as per the following details:

#### **MOTOR GENERATOR:**

Motor — Volt D.C., shunt interpole, flat speed regulation. 1875 rpm. Generator — 220 volt, 500 cycles, special wave form alternator, designed specially to operate with remainder of transmitting unit. (We reserve the right to furnish our new type, (patents pending) interpole alternator with variable wave form). Both types have very close VOLTAGE regulation and high over all efficiency. Spares: 4 sets brushes. PROTECTIVE APPLIANCES, will be supplied.

#### **TRANSFORMER:**

Type: Open core, dry, specially designed to operate without exterior resistance with remainder of transmitting unit. Spares: 2 secondary sections.

#### **ARMORED IRON CASE:**

New design, perfect cooling by special central draft. (We reserve right to furnish our new type tubular gap). This latter having new feature of cooling and perfect sparking alignment with ease of dismantling).

#### **LOW TENSION SWITCHBOARD:**

Black slate, angle supports, on which will be mounted:

1. C.E. Hot wire voltmeter,
1. C.E. Hot wire ammeter,
1. C.E. Single phase wattmeter,
1. Hartman & Braun Reed type frequency indicator.

(All instruments calibrated for 500 cycles).

#### **AUTOMATIC MOTOR SEARCHER:**

Special contactors for distant control of A.C., line and field; besides motor control.

Generator and motor field rheostats, etc., as per photographs.

#### **TRANSMITTING INDUCTANCES:**

New type, (patents pending) transmitting inductances will be supplied giving continuously variable wave length of 600 to 2000 meters with no switches, exciting and radiating circuits, always in resonance and with maximum coupling. This type of inductance is absolutely new and gives the widest range of inductance variation of any known form of inductance.

#### **TRANSMITTING CONDENSERS:**

Standard type W.S.A.Co's. copper deposit jars in Rack. Capacity, .02 Mfd.,

OR

We should prefer to furnish our new design plates in absolutely oil tight tanks and cases. This latter type occupies very much less space than the jar type of same capacity.

#### **RADIATION METER:**

Hartman & Braun hot wire type, 0-30 amperes, unshunted type.

#### **TRANSMITTING KEY:**

Magnetic relay type. A very efficient key capable of operating at a maximum speed of 60 words per minute. Hammer blow type. Signalling accomplished by means of small Morse key.

#### **ANTENNA SWITCH:**

Mounted on high tension switchboard panel.

#### **LIGHTNING SWITCH:**

As per photograph submitted.

#### **HIGH TENSION SWITCHBOARD:**

White marble, same dimensions as low tension switchboard, mounted complete with the following apparatus:

Quenched spark gap.

Wave length and coupling control handles with indicators.

(continued)

2723  
raj-44  
(Sheet #2 - continued)

Radiation Meter,  
Change-over switch,  
(Transformer, condenser and inductances mounted on  
back of board.)

**RECEIVING APPARATUS:**

**Three Receivers.**

- (a) New Type 1913, 1-P-76, complete receiver, special design for receiving wave lengths up to 10,000 meters. Highly selective.
- (b) New Type 1913, 1-P-76, complete receiver, for receiving wave lengths of 300 to 4200 meters. Highly selective.
- (c) New Type 1913, 1-P-76, complete receiver, for receiving wave lengths of 300 to 4200 meters. Simplified type for stand-by conditions.

(b) and (c) will be provided with a Listening-in-key and special phones.

All these receivers are furnished with standard HERTZ and SILICOX ALEXANDER detectors and are arranged for very efficient spark group frequency tuning. 3 pairs Richard adjustable telephones furnished with each set. Telephones can be furnished if desired to be strongly responsive or selective to 1000 sparks per second. Spares as called for in requisition will be supplied.

**WAVE LENGTH:**

Type P. W. M., will be supplied.

**DELIVERY:**

One set to be delivered within fifty-three (53) days from date of contract.

One set to be delivered within seventy-eight (78) days from date of contract.

**PRICE:**

The price to be \$3599.00 per set, making a total of \$7198.00.

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# PLAINTIFF'S EXHIBIT 69

## NAVY PAY OFFICE CONTRACT.

CONTRACT No. 21

SERIES 1214

PAY OFFICE - PHOENIX, ARIZ.

ACCOUNT OF

Req'n No. 186 B. H. A.  
Station Bureau Steam Engineering  
App'n Coal, Lost Advances, B. A. (Capt. of vessels  
1914, ...)

This Contract, of two parts, made and concluded this 31st day of

A. D. 1924, by and between

**W. H. & C. H. Co.,**  
**Columbia St., Seattle, Washington,**

party of the first part, and the UNITED STATES

Naval Pay Office, United States Navy Pay Office, Washn. D.C.,

under the direction of the Secretary of the Navy, party of the second part, WHEREAS:

in consideration of the payments hereinafter specified, the party of the first part,

and 128 personal and legal representa

hereby covenant and agree to and with the party of the second part, as follows:

1. That the said party of the first part, will furnish and deliver, at its own expense, at such place to the Navy Yard, Mare Island, Cal., & New York, N.Y.

thereof may direct, and within 240 days from the date of this contract,

following articles, and at the price set opposite each item, respectively

2224 use following articles to be omitted from the specifications:

Revolving switch, \$15.00 per set  
Cableless switch, 40.00 " " Total for 5 sets: \$205.00

Total Cost: \$1,186.00

### ARTICLES REQUIRED

Reference No.

Reference

FOR DELIVERY AT NAVY YARDS NEW YORK AND MARE ISLAND,

Req. 186 B. S. A.

Item 1. Five (5) 5-k.w. radio sets for ship installations.

To be in accordance with "Specifications 16-R-1", issued by the Navy Department January 10, 1916, except as modified below:

1. Panel assembly of the transmitter shall be required and, if offered, the different parts shall be suitable to ready removal and separate individual parts.

2. Switchboard shall include a switch for the alternator-cumulator circuit and the other side of the motor field.

3. The automatic starting panel required by para. 3 and the transfer switch required by para. 4 shall be installed in the radio room, and the starter to be operated by a push button switch located on the radio panel.

4. In lieu of para. 14 (a) (1) alter the following: "The set shall contain a switch to disconnect the set from the main power supply and to disconnect the set from the motor field."

Approved by: *[Signature]* Date: 10/1/44  
 Approved by: *[Signature]* Date: 10/1/44

at the time of the test  
 the apparatus shall be  
 capable of continuous operation  
 at a room temperature  
 of 50° C. and a humidity  
 of 90% saturation. No  
 part of the transmitting  
 apparatus having cotton  
 insulation shall show a  
 final temperature greater  
 than 90° C. and no other  
 part of the apparatus  
 shall show a final temperature  
 greater than 100° C.  
 The test shall be made  
 at full power at a sending  
 rate of about 20 words  
 per minute; power to be  
 measured with key depressed.

5. Under par. 24(b) add: "Contract number and requisition number."

6. In lieu of paragraphs 25(f) and 25(g), substitute the following:

"All apparatus, including transmitters and receivers, shall be capable of continuous operation at a room temperature of 50° C. and a humidity of 90% saturation. No part of the transmitting apparatus having cotton insulation shall show a final temperature greater than 90° C. and no other part of the apparatus shall show a final temperature greater than 100° C., not shall any part of the apparatus show deterioration or faulty operation. Continuous operation shall be based on a test for a period of eight consecutive hours at full power at a sending rate of about 20 words per minute; power to be measured with key depressed."

7. Condenser for protective appliances required by par. 21 (a)(4) shall be of not less than 0.05 mfd. instead of 0.1 mfd. capacity.

8. Paragraph 21(c) of the specifications 16-R-1 required that protective appliances shall be provided for use in the following locations:

- (1) Across the terminals of the low tension winding of the transformer, 2 sets, 1 for each transformer.
- (2) Across the terminals of the armature of the alternator, 2 sets, 1 for each alternator.
- (3) Across the terminals of the fields of the alternator, 2 sets, 1 for each alternator.
- (4) Across leads to cooling motor for each gap.

Paragraph 21(d) requires protective appliances as specified for each D.C. motor of the two motor-generators.



9. The spare parts, including spare brushes, gas-  
meters, contacts, fuses, quenched gap plates, spacers for blower  
motor, etc., provided with each set, except those for the  
motor-generator and except the spare condenser units, shall  
be delivered in a suitable hardwood box with metal hinges  
and lock. The box shall be suitably fitted to hold the spare  
parts securely and each spare part shall be readily removable  
without disturbing the other contents of the box.  
The spare parts for the motor-generator shall be provided  
in a separate box.

10. Bidders shall state what reduction will be made  
from prices offered in case the government, at its option,  
accepts any or all of the following apparatus:

- (1) Lightning switch.
- (2) Antenna transfer switch.
- (3) Condenser rack.
- (4) Wave changing switch.
- (5) Oscillation transformer.

11. The unit price for each set shall include all  
spare parts as required by the specifications and as offered  
but an itemized list of the spare parts as required by the  
specifications and as offered must accompany each bid and  
the unit price of each spare part so offered must be stated.  
This information is desired for future reference in placing  
orders for spare parts. The particular attention of bidders  
is invited to this paragraph, and the preceding paragraph,  
which must be strictly complied with. Failure to meet  
the requirements of these paragraphs will render the bid  
liable to rejection.

12. Liquidated damages for delay in delivery shall  
be calculated at the rate of \$100.00 per day per set. If  
each set not delivered complete at the expiration of the  
contract period.

Delivery to be made within 60 days from date of con-  
tract. Delivery of the first two sets to be made at the  
Navy Yard, New York, and of the other three sets at the  
Navy Yard, San Diego, Cal.

**This Contract, of two parts, made and concluded this twelfth day of January, A. D. 1914, by and between Radio Telephone & Telegraph**

**of 806 Broadway, New York,**

**in the State of New York, party of the first part, and the UNITED STATES, by the Purchasing Pay Officer, United States Navy Pay Office, New York, N. Y.**

**acting under the direction of the Secretary of the Navy, party of the second part. Witnesseth, That, for and in consideration of the payments hereinafter specified, the party of the first part, for itself and its personal and legal representatives, doth hereby covenant and agree to and with the party of the second part as follows:**

**1. That it (the said party of the first part, will furnish and deliver its own risk and expense, at such place in the Navy Yard, Brooklyn, N. Y.**

**as the Commandant thereof may direct and within thirty days from the date of contract, the following articles, and at the price set opposite each of the same:**

Specification No. 184, Bureau. Naval Supply Department.	
PART 1 - Title	
10 Audion amplifiers, complete,	400.00 each
1000 double bulbs for same,	2.50 "
4 sets relay and bell for use with Audion amplifiers,	50.00 set
2 Loud-speaking horns for use with Audion amplifiers,	50.00 each
To be equal to samples submitted for test at the Bureau of Standards, Washington, D. C. At the Radio Telephone Company, New York, N. Y.	
TO BE DELIVERED to the General Storekeeper, Navy Yard, Brooklyn, N. Y.	

any copy of material received or approved shall be removed by the majority of the first part at **the** own expense, and within ten days after notification.

[illegible][illegible]

the authors are grateful to the referees for their valuable comments and suggestions. The authors are also grateful to the anonymous referees for their constructive comments and suggestions.

Radio Telephone &amp; Telegraph Co.

Sixty Eight Hundred & 00/100 Dollars ----- (\$6800.00)-----

1. The first step in the process is to identify the problem or issue that needs to be addressed. This involves gathering information and understanding the context of the situation.

For the purpose of this study, the authors have identified a set of 1000 words that are used in the text of the 1000 most common words in the English language.

[illegible]

1919-2020

Figure 1.  $\sigma^2$  vs.  $n$  for  $\lambda = 0.001$  and  $\lambda = 0.01$ .

as the policy of the first part

Ed. J. J. . . .

(b) Rechtsanwalt

na to Purchasing Pay Office:

Pay Director U. S. N. Purchasing Power Index

U. S. Navy Pay Office, New York, N. Y.

*Note.*—Documents signed by a firm must be also signed by the firm either by a member of the firm or otherwise; documents signed by a partnership shall be signed by no other person, and sealed with the corporate seal, if signed by any other person not so authorized. The signature of each partner shall be appended to the evidence of authority to sign.

U. S. GOVERNMENT  
To be used when the contractor  
agrees to furnish delivery, and the  
time for delivery is within thirty  
days.

MANHATTAN OFFICE  
**CONTRACT.**

CONTRACT No. 1000  
SERIES 1000  
PAY COVERED BY 1000

ACCOUNT OF Station Bureau Steam Engineering,  
Appn. Coast-Asst-Admiral, USA  
Light of Vessels, 1914, S. R.

This Contract, of two parts, made and concluded this 27th day of  
June, A. D. 1914 by and between

**Radio Telephone & Telegraph Co.**

of **370 Broadway, New York City**

in the State of New York, a party of the first part, and the UNITED STATES, by  
its Chief of Bureau, United States Navy Pay Office, Washington, D.C.,

whereby the Government of the United States, a party of the second part, Witnesseth, That,  
for the consideration of the sum of money hereinafter specified, the party of the first part, for

its and its personal and legal representatives, does

hereby covenant, agree, bind and with the party of the second part, as follows: viz.

That it, the said party of the first part, will furnish and deliver, at its own  
expense, at such place in the Navy YARD, WASHINGTON, D.C.,

within thirty days from the date of this  
contract, the following articles, and at the prices set opposite each item respectively:

Item 1.	110.00 each
" 2.	200.00 "
" 3.	500.00 "
" 4.	500.00 "
" 5.	5.00 "
" 6.	2.00 "
Total.	17,625.00

- Item:
- 30 single ultrasonic detectors, complete with 6-volt Hudson filament, double bulb, without telephone receivers.
  - 4 ultrasonic detectors, complete with 12-volt Hudson filament, double bulb, and telephone receivers.
  - 2 receiving cabinets, complete.  
To be specially designed for use with and to include 6 volt Ultrasonic detector. Detector and receiving circuits to be in separate cabinets. Range of wave lengths of receivers to extend to 10,000 meters.
  - 2 receiving cabinets, complete. To be specially designed for use with, and to include, 12 volt ultrasonic detectors. Detector and receiving circuits to be in separate cabinets. Range of wavelengths of receivers to extend to 10,000 meters.
  - 200 Hudson filament, 6 volt, double bulbs, for use with Item 1.
  - 25 Hudson filament, 12 volt, double bulbs, for use with Item 2.

Each bulb supplied under Items 5 and 6 shall be enclosed in a separate container. The container shall be suitably inscribed with a description of the enclosed bulb which will indicate exactly the apparatus with which it is to be used, in order to prevent confusion with bulbs of similar appearance designed for other purposes. Preferably containers for bulbs of different classes should be readily distinguishable through differences in shape or color of markings.

Each piece apparatus supplied under items 1, 2, 3 and 4 shall be accompanied with full wiring diagram and detailed instructions for the care and operation of the same.

The best workmanship and material shall be employed throughout.

To be shipped at place of delivery, and subject to approval after inspection.

PLAINTIFF'S EXHIBIT 75

2730

**Radio Telephone & Telegraph Co.,**  
**New York City,**  
**Account of**  
**Radio Telephone Engineering,**  
**App's**  
**Radio Telephone Engineering, RIA**

**This Contract,** of two parts, made and concluded this **27th** day of **July**, A. D. 19**35**, by and between

**Radio Telephone & Telegraph Co.,**  
**New York City,**

of the State of **New York**, party of the first part, and the UNITED STATES  
 by the Purchasing Pay Officer, United States Navy Pay Office,

acting under the direction of the Secretary of the Navy, party of the second part, **Witnesseth**, that

for and in consideration of the payments hereinafter specified, the party of the first part,

for **itself** and **its** personal and legal representatives

hereby covenant and agree to and with the party of the second part, as follows:

1. That the said party of the first part, will furnish and deliver, at **its** own

risk and expense, at such place in the Navy **its** the

thereof may direct, and within **Washington, D.C.**

the following articles, and at the price set opposite each item, respectively:

**Cost: Items 1. \$450.00**  
**2. 10.00 ALL: \$2,350.00**

- Item  
 1. 5 20-watt generator Audion sets. To be complete with small high-voltage generator in lieu of B battery, rheostat, switches, impedance, "grid-stunt", etc., but without condensers or inductances. Motor-generator to be adapted to operation on a.c. current supply of 110-120 volts.

- Item  
 2. 10 spare bulbs for above  
 Inspection after delivery.

P. Cert. 1.



2731

SOUTHERN DISTRICT

MANCINI WOOD & CO. LTD.  
COMPANY

PLAINTIFFS

VS

DeFOREST RADIO TELEPHONE &  
TELEGRAPH CO. (INCORPORATED)  
DeFOREST.

DEFENDANTS

IN EQUITY  
No. 12-31

~~PLAINTIFFS' EXHIBIT NO. 14~~

PATENTS AND DESIGNS ACT, 1907.

IT IS HEREBY CERTIFIED by the Comptroller-General of Patents,

Designs and Trade Marks that on the 16th November, 1904, John Ambrose Fleming, of University College, Gower Street, in the County of London, Doctor of Science, made an application (with provisional specification) for a Patent for an invention the title of which is "Improvements in instruments for detecting and measuring alternating electric currents"; that the application in question was numbered 24,850 of 1904; and that a complete specification (including drawings) was left in connection therewith on the 15th August, 1905.

It is also certified that the said complete specification was accepted and placed open to public inspection on the 21st September, 1905; that a Patent was granted in respect of the said application on the 7th December, 1905, and sealed as of the 16th November, 1904; and that the annexed are true copies of the provisional specification and complete specification and drawings as accepted.

This certificate is issued for use in legal proceedings in the United States of America.

FLEMING BRITISH PATENT #24,850  
✓  
EXHIBIT #77

WITNESS my hand this 9th day

of April, 1915

*W. Temple Evans*

Comptroller-General of Patents,  
Designs and Trade Marks.

THE PATENT OFFICE,  
25, SOUTHAMPTON BUILDINGS,  
LONDON, W

2358

2731A

ERRATUM.

SPECIFICATION No. 24,850 A.D. 1904.

Page 4, line 11, for "Figure 7" read "Figure 1"

PATENT OFFICE,

22nd February, 1906.

[Second Edition.]

N<sup>o</sup> 24,850

A.D. 1904

*Date of Application, 16th Nov., 1904**Complete Specification Left, 15th Aug., 1905 - Accepted, 21st Sept., 1905*

## PROVISIONAL SPECIFICATION.

**Improvements in Instruments for Detecting and Measuring Alternating Electric Currents.**

I JOHN AMBROSE FLEMING of University College, Gower Street, in the County of London, Doctor of Science, do hereby declare the nature of this invention to be as follows;

It is well known that alternating electric currents can only be detected and measured by the use of some instrument, the indications of which do not depend upon the direction of the current. Hence an instrument of which the indication is dependent upon the heating of a wire by the current commonly known as a hot wire instrument is suitable for the above purpose. Also one depending upon the attraction or repulsion of electric current, commonly known as an electro-dynamometer, because in both these cases the indication or reading of the instrument is the same even if the current direction is reversed.

On the other hand, an ordinary galvanometer of the movable needle or movable coil type cannot by itself be used for detecting or measuring alternating currents because it only gives an indication with a unidirectional current and is therefore unaffected by an alternating current.

The object of my invention is to provide a means by which an ordinary galvanometer can be used to detect and measure alternating electric currents and especially high frequency alternating currents commonly known as electric oscillations.

The means I employ for this purpose consists in the insertion in the circuit of the alternating current of an appliance which permits only the passage of electric current in one direction and constitutes therefore an electrical valve.

I construct it as follows:—

In a glass bulb, I send two or more carbon filaments such as are used for the manufacture of electric lamps. These filaments each have their own separate terminals. One or more of these carbon filaments may be replaced by loops of platinum wire, provided at least one carbon filament is used. A high vacuum must be made in the bulb. Two such bulbs are employed and for the sake of simplicity, I may describe the mode of use when a double carbon filament in each bulb is used. The two bulbs are each associated with a small insulated primary or secondary battery of sufficient voltage to bring one of the filaments to bright incandescence of greater intrinsic brilliancy than if used as an incandescent lamp. The bulbs are connected in parallel with each other and inserted in the alternating current circuit, but so that an incandescent filament and a dark or cold filament in each bulb form the electrode or connection for the current to be measured to enter and leave the bulb.

In series with one of the bulbs is placed an ordinary galvanometer. In the two branch circuits formed of the two bulbs, one in series with a galvanometer the local insulated batteries are arranged to ignite carbon filaments at opposite ends. That is to say, the carbon filament nearest to one common terminal is the ignited filament in one bulb and that farthest from the same common terminal in the other bulb.

*Instruments for Detecting and Measuring Alternating Electric Currents.*

These bulbs have the property that inside the bulb, negative electricity can move from the hot to the cold carbon filament even under a very low electromotive force but it cannot move in the opposite direction. Hence, owing to the arrangement of the bulbs, the alternating current arriving at the common terminal splits and all the positive alternations pass through one bulb and all the negative through the other bulb. The galvanometer is therefore affected solely by currents flowing in one direction. The bulbs serve the purpose of separating out the two constituents of the alternating current.

In place of two bulbs, one only may be used in series with a galvanometer and then the bulb only allows currents to pass in one direction and the galvanometer gives an indication.

The device is especially applicable to the detection and measurement by an ordinary galvanometer of high frequency electric currents or oscillations, where any form of mechanical or electrolytic rectifier is useless.

I construct the bulbs with two or more sets of carbon filaments.

One set when rendered incandescent forming one electrode of the valve and the other set kept cold, the other electrode.

In place of carbon filament for the cold electrodes I use sometimes, loops of platinum wire or platinum wires with plates on the end.

In making the connections of the bulb to the alternating current circuit it is essential to join one end of the galvanometer wire to that terminal of the hot carbon filament to which the negative end of the local or heating battery is applied.

The other end of the galvanometer and the two ends or all the ends of the cold filaments taken together constitute the terminal of the indicating appliance.

The carbon filament may also be heated by part of the alternating current which is being rectified or measured.

Any other method of heating one or more of the carbon filaments may be employed.

The above described multiple carbon filament bulb and a galvanometer may be used as a receiving instrument in wireless telegraphy.

For this case, the aerial receiving wire has the primary circuit of an oscillation transformer inserted in it and one of the above described electrical valves and a galvanometer are inserted in the secondary circuit.

The feeble alternating currents excited in the aerial by electric waves, then make themselves evident by indications in the galvanometer.

Dated this 16th day of November 1904

J. A. FLEMING

## COMPLETE SPECIFICATION

**"Improvements in Instruments for Detecting and Measuring Alternating Electric Currents."**

I, JOHN ARTHUR FLEMING, of University College, Gower Street, in the County of London, Doctor of Science, do hereby declare the nature of this invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement:

This invention relates to instruments for detecting and measuring alternating electric currents, and more particularly to instruments for detecting and measuring high frequency electric currents or oscillations, where any form of mechanical or electrolytic rectifier is useless.

*Instruments for Detecting and Measuring Alternating Electric Currents.*

Such instruments as the latter are not affected by alternating electric currents either of high or low frequency which can only be measured and detected by instruments called alternating current instruments of special design. It is, however, of great practical importance to be able to detect feeble electric oscillations, such as are employed in Hertzian wave telegraphy by an ordinary movable coil or movable needle mirror galvanometer. This can be done if the alternating current can be "rectified", that is either suppressing all the constituent electric currents in one direction and preserving the others, or else by changing the direction of one of the sets of currents which compose the alternating current so that the whole movement of electricity is in one direction. Many means have been devised and are in use for rectifying low frequency alternating currents, such as are used in electric lighting. There are well known forms of mechanical rectifier, also there is a well known form of electro-chemical rectifier depending on the fact that when a plate of carbon and aluminium is placed in any electrolyte which yields oxygen on electrolysis, an electric current can only pass through this cell in one direction if below a certain voltage.

Both these forms of rectifier are however inapplicable for high frequency currents. I have found that the aluminium-carbon cell will not act with high frequency currents.

I have discovered that if two conductors are enclosed in a vessel in which a good vacuum is made, one being heated to a high temperature, the space between the hot and cold conductors possesses a unilateral electric conductivity, and negative electricity can pass from the hot conductor to the cold conductor but not in the reverse direction.

As the hot conductor should be heated to a very high temperature say near to the melting point of platinum ( $1700^{\circ}$  C.), it should be of carbon preferably in the form of a filament such as is used in any ordinary incandescent electric lamp. The cold conductor may be of many materials, but I prefer a bright metal such as platinum or aluminium or else carbon.

The two conductors are enclosed in a glass bulb similar to that of an incandescent lamp, and I generally heat the carbon filament to a high state of incandescence by a continuous electric current, the electrical connection to the filament and the cold conductor being made by platinum wires, sealed air tight through the glass.

Figure 1 is a full size sectional elevation of an instrument constructed according to this invention, the electrical connections being shown diagrammatically. This figure illustrates the application of the invention to wireless telegraphy.

Figures 2 and 3 show modifications to smaller scales.

In Figure 1, *a* is a glass bulb, and *b* is a carbon filament like the carbon filament of an incandescent lamp, suitable say for taking a current of 6 to 8 amperes and 2 to 4 inches. *c* is a cylinder of aluminium open at the top and bottom, of length 2 inches but does not touch the filament. The cylinder *c* is suspended in the bulb by the thin wires *d*, and the ends of the filament *b* are connected to the wires *e* and *f* to the box *g* and *h*. The platinum wires are sealed air tight through the glass in the ordinary manner.

As a high vacuum should be obtained in the bulb *a* and as a considerable amount of air is excluded in the conductors these should be heated when the bulb is being exhausted. The filament *b* can be conveniently heated by passing a current through it whilst the cylinder *c* can be heated by surrounding the bulb with a resistance coil through which a current is passed the whole being enclosed in a box lined with asbestos or the like. When as hereinafter described a cold conductor *e* is replaced by any form of conductor which can be heated by passing a current through it this method is usually more convenient than that just described.

The carbon filament is made highly incandescent in the usual way by a continuous electric current produced by the battery *k* the negative pole of which is connected to the wire *e* and the positive to the wire *f*. The wires *d* and *e* are

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connected together by a wire  $j$  which completes the circuit through the secondary winding  $k$  of an induction coil (such as is ordinarily used in wireless telegraphy) and a galvanometer  $l$ .  $m$  is the primary winding of the induction coil having one end connected as is usual to an aerial wire  $n$  and the other to earth  $o$ . The arrangement described above operates as an electric valve and permits negative electricity to flow from the hot carbon  $b$  to the metal cylinder  $c$  but not in the reverse direction so that the alternations induced in the coil  $k$  by the Hertzian waves received by the aerial wire  $n$  are rectified or transformed into a more or less continuous current capable of actuating the galvanometer  $l$  by which the signals can be read.

Although Figure 1 shows the application of the instrument to wireless telegraphy it will be understood that the aerial wire  $n$  may be replaced by any current in which there is an alternating electromotive force, whether of low frequency or of high frequency.

I may increase the effect in the following manner: I employ two bulbs arranged as shown in Figure 2 each being similar to that shown in Figure 1.  $p, p$  are the two coils of a differential galvanometer connected to the bulbs in such fashion that currents flowing in opposite directions through the two bulbs, flow in the same direction round the two coils of the galvanometer as regards the needle  $q$  of the galvanometer itself. For this purpose the hot conductor of each bulb is connected to the cold conductor of the other, hence, one bulb permits negative electricity to flow only in one direction and the other bulb permits only negative electricity to flow in the opposite direction through it. The common terminal of the two galvanometer coils  $p$  is connected to the coil  $k$  or any source of alternating electromotive force or of electrical oscillations, the other terminal of the said source being connected to the bulbs as shown. Each bulb has its own separate insulated battery  $h$  for heating its hot filament.

Under these circumstances, alternating electric currents are split into two continuous currents passing through the two bulbs in opposite and, in the two coils of the galvanometer, in the same directions.

By thus using a differential galvanometer I make use of the whole of the energy of the alternating current instead of discarding half of it. In this manner very feeble electrical oscillations can make themselves apparent by the indication which they give on a sensitive mirror galvanometer.

A number of these valves may be associated together in parallel as shown in Figure 3 so that alternating currents rectified by them separately may produce continuous currents which are added together.

In place of using a metal cylinder surrounding a carbon loop filament, I sometimes use a number of carbon filaments. Some of these are heated by means of an electric current, and become the hot conductor of the oscillation valve and the others remain cold and form the cold conductor. Or the metal cylinder may be replaced by a cylinder of meerschauum or the like having wound helically upon it a narrow ribbon of metallic foil.

The galvanometer  $l$  may be replaced by any other instrument for detecting the oscillations or by a relay for actuating a detecting or recording instrument.

In those cases in which a larger alternating current has to be dealt with, the hot conductor may be a rod of soft graphitic carbon held in suitable supports.

I find it possible by means of the device described above to rectify an alternating current without the use of any auxiliary continuous heating current. Thus, if I pass through the carbon filament an alternating current to bring it to bright incandescence, I find if I connect either terminal of the filament by a circuit outside the bulb with the terminal of the embracing cylinder or other cold conductor, then in this circuit a continuous current flows. Hence, the device may be used for rectifying either high frequency or low frequency alternating currents of electrical oscillations, provided these are of sufficient strength to render a carbon filament brilliantly incandescent.

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Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed I declare that what I claim is:—

1. A vacuum vessel having in it two conductors adjacent to but not touching  
5 each other, one of them being heated, these conductors being connected by a circuit outside the vessel, such circuit being exposed to some influence tending to produce an alternating current in it and which contains a galvanometer or other instrument for detecting a continuous current substantially as described.
2. In instruments such as are covered by Claim 1, heating the conductor by  
10 means of a continuous electric current passed through it substantially as described.
3. The application of the instruments covered by Claims 1 and 2 to wireless telegraphy substantially as described.
4. Duplicating the instruments covered by Claims 1, 2 and 3, by connecting  
15 the two coils of a differential galvanometer respectively to the heated conductor in one vessel and the unheated conductor in the other, the connection between the two coils being connected to the other pair of conductors substantially as described.
5. Instruments for converting alternating electric currents into unilateral  
20 currents substantially as described.

Dated this 1st day of August 1905.

J. A. FLEMING.

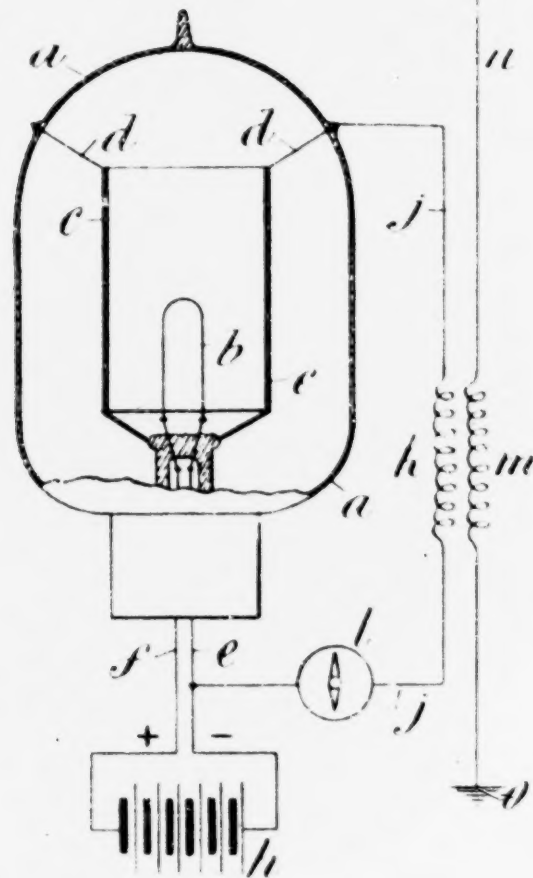
Redhill Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.

[G. 9058—(25—1/1906.)]

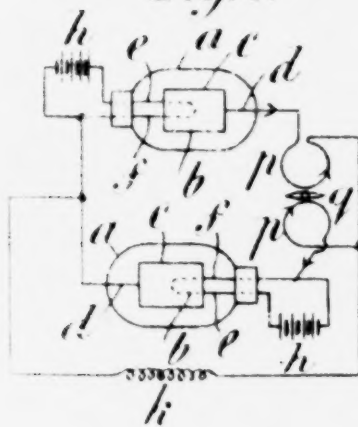
*2. 3. 4. 5.*

2364

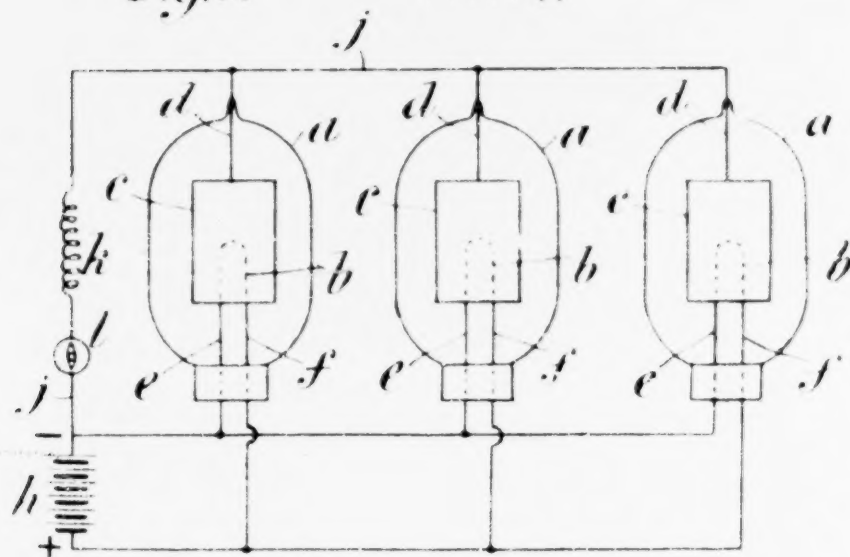
*Fig. 1.*



*Fig. 2.*



*Fig. 3.*



PLAINTIFF'S EXHIBIT 78  
(1913 Navy Manual)

2738-2740

58

MANUAL OF WIRELESS TELEGRAPHY.

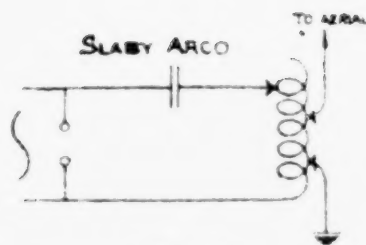


FIG. 29A



FIG. 31

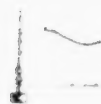
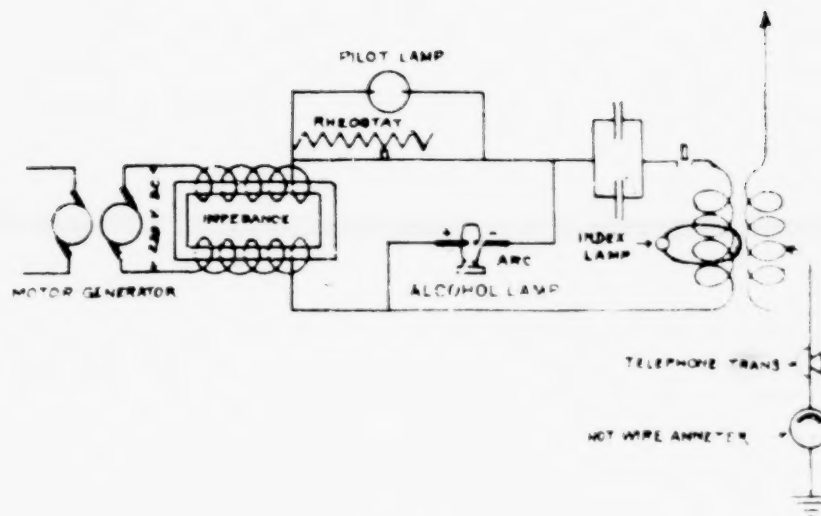


FIG. 33—Earthed Electric Waves

2365-2367



2741-2746

FIG. 82

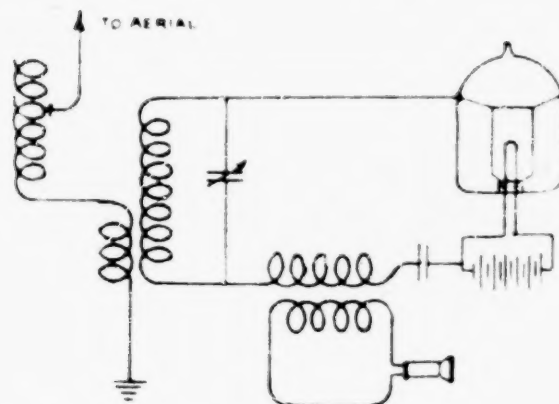


FIG. 83 VALVE RECEIVER - MARCONI

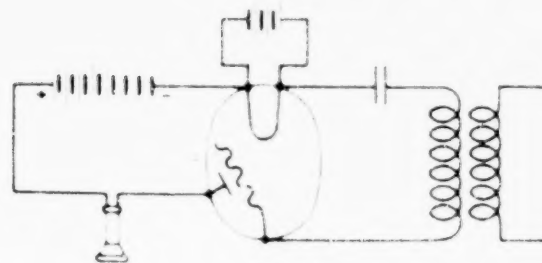


FIG. 88

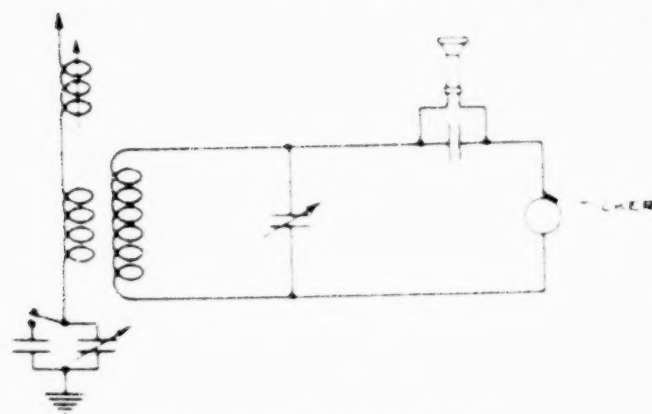
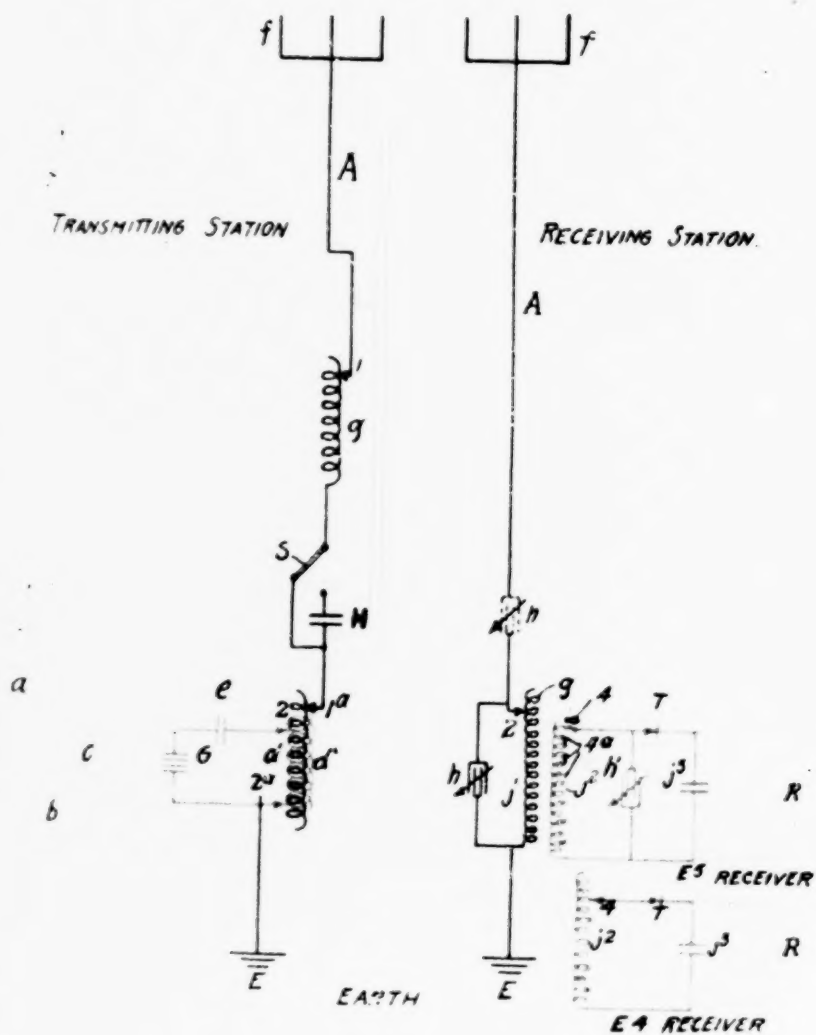


FIG. 89 - Federal Co. (Poulsen)

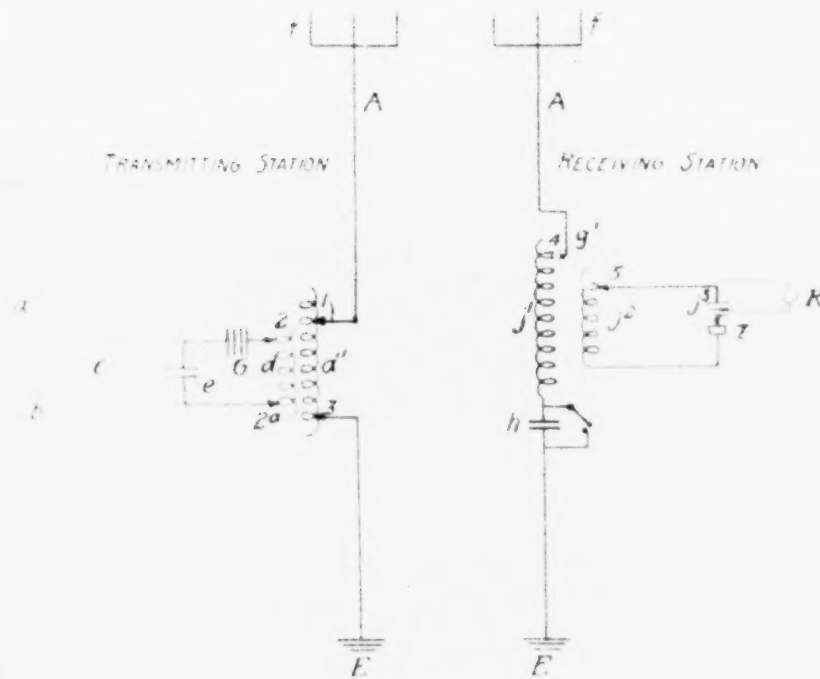
TELEFUNKEN TYPE.



(6) 2375 | PLAINTIFF'S EXHIBIT 80, DRAWING NATIONAL  
ELECTRIC SUPPLY COMPANY APPARATUS

Plaintiff's Exhibit 80

NATIONAL ELEC SUPPLY CO. TYPE  
FIELD RADIO PACK SET



[fol. 2376] PLAINTIFF'S EXHIBIT 84, OFFICIAL INSTRUCTIONS FOR USE OF ULTRA AUDION

Subject: The Ultraudion—Its use with the various models of the 1-P-76 receivers in the U. S. Navy Radio Stations on board ship and on shore.

1. The Ultraudion, or oscillating audion, is very much more sensitive than the best crystal detector. Its great superiority over the ordinary detector, in both uniformity and sensitivity, more than makes up for the few new difficulties that will be met in learning to operate it. All the connections of the Ultraudion are given in the attached diagram. The three tables at the end of these instruction sheets give the approximate ranges, for the three models of the 1-P-76 receivers, within which the Ultraudion will oscillate, and also the size of the loading coils and parallel condensers that will be necessary when working on the very long wave lengths. The measurements were made on an antenna with a fundamental wave length of 440 meters and a capacity of 0.00126 mfd., which is fairly representative of the ordinary ship's installation. When the audion is connected as shown in Figure 1, it is many times more sensitive than the old audion connection, even when it is not in the oscillating condition. When not oscillating it also preserves the distinctive note of a spark station but will not make sustained oscillations, such as are given out by an arc or a high frequency machine, audible.

Description of the Audion

2. The audion has three elements which are sealed in the bulb. They are the filament, one pair of grids and one pair of plates. The connections to these elements are brought out in four wires, two of which are for the filament, while the other two are one for the pair of grids and one for the pair of plates. The lead to the plates is red while the lead to the grids is green. An easy way to remember the grid connection is that G stands for grid and green. The filament is lighted by a 6-volt storage battery, the voltage being regulated by means of a series rheostat. The filament is rated at  $3\frac{1}{2}$  volts and about  $\frac{3}{4}$  amperes.

Description of the Ultraudion Circuit

3. The receiving circuit itself consists of two parts, the primary or the antenna circuit, and the secondary or the

inductively coupled circuit. The primary circuit is the ordinary circuit as found in the various models of the 1-P-76 receivers. A condenser in series with the antenna is shown in the diagram. When used in this position more [fol. 2377] inductions will have to be cut in. It is best to use a variable series condenser with a total capacity of 0.001 mfd. When receiving sustained oscillations the series condenser will actually strengthen the signals, and while it is not so good for spark signals it allows a finer adjustment of resonance than would be possible with inductance varied in steps. For wave lengths longer than the range of the primary inductance it will be necessary to put this condenser in parallel with the antenna, but doing this will decrease the strength of signal especially when the parallel capacity is large.

4. In the 1-P-76 1912 model and 1-P-76 improved model the two leads to the ultraudion circuit are connected to the secondary inductance binding posts which are also common to the condenser. The telephone and the detector connections on the sets are left *open*. In the 1-P-76 1914 model there are two fixed secondary condensers, one for the short wave and one for the long wave coils. These condensers are connected to the slide rods of the two secondaries, and will have to be disconnected and a double pole, double throw knife switch mounted on the end of the receiver case. To one set of clips on the switch connect the slide rods of the short wave secondary; to the other set of clips connect the long wave secondary rods and to the pivots of the switch connect the outside variable tuning condenser of about 0.0018 mf.

5. The ultraudion circuit has two leads running to it. One of them is connected directly to the plate or R binding post while the other is connected to the grid or G binding post through the variable condenser GC of about 1.001 mfd. total capacity. The condenser must be in this lead and not in the plate lead. Six binding posts on the audion box are used. The two marked S<sub>1</sub> S<sub>2</sub>, "To tuner," or Ra Re, are not to be used. The R, G, A-, A-, and the two telephone posts are sufficient as the diagram shows. The bridging condenser BC is connected from A- to the R post, and should have a total capacity of 0.002 mfd. and be variable. Connect the telephones in the posts marked "Telephones" on the audion box. The circuit is now ready for use.

### Method of Obtaining Oscillations

6. Draw secondary inductance out as far as possible from the primary.

(2) Set secondary tuning condenser C at 0°.

(3) Set bridging condenser BC at 0°.

(4) Cut in 80 turns of secondary inductance for either of the 1912 models of 1-P-76, or 30 or 40 turns of the 1914 model short wave secondary.

(5) Set the grid condenser GC at 40°.

(6) Bring filament to a fair brightness.

[fol. 2378] (7) Vary B battery step by step and tap with the finger on the inductance side binding post of the grid condenser, or at the point shown in the diagram. When the bulb is in the oscillating condition a click will be heard in the telephones when the finger touches the post and another when the finger is removed. The tapping should be very frequent and the condensers should be kept *very* close to the points mentioned above. As you tap vary the A and the B battery voltages. The oscillating point is but very little below the point where the blue arc appears. On wave lengths up to 1500 meters the bridging condenser should never be raised above 10°, neither should the grid condenser be below 15°. On account of the high resistance of the secondary inductance not more than 30° can be used on the secondary condenser with the best bulbs, and often not more than 10°. This applies to the 1912 models of the 1-P-76 where the capacity of the condenser is about 0.0018 mfd. This size of condenser is also large enough for the 1912 model 1-P-76.

7. There are two good ways of determining whether a bulb is in the oscillating condition. The first is by hearing the double click mentioned above. The second method is the use of a testing buzzer. If the bulb is oscillating the cellar note of the buzzer will be roughened. If the oscillations stop they can generally be restarted by bringing the secondary tuning condenser back to 0°.

### A Device for the Prevention of Deadening of the Bulb Due to Strong Signals and Static Shocks

8. In figure 1 there is shown a double carborundum contact which connected across the grid and the filament. The object of this contact is to prevent the killing of the bulb

due to very heavy signals and some kinds of static shocks. It will be necessary to use it in stations where strong interfering signals are met with and in fleet work. It is not intended as a static preventer. Any carborundum can be used and the contact need not be light; in fact, there is not much choice in the contact.

#### Causes of Failure to Produce Oscillations

9. Some bulbs will not oscillate so it is best to try several, remembering to vary the A and the B battery voltages. Vary the condensers *slowly*. Sometimes reversing the R and the G leads of the bulb will clear up the trouble because frequently bulbs are found that have reversed leads. Another trouble is indicated by failure to produce a blue arc. If it is impossible to strike the blue arc the trouble lies in the B battery not having sufficient voltage, or the connections are wrong, or the bulb is improperly exhausted. B battery trouble is located by varying the voltage and if sharp clicks are not heard, provided connections are per [fol. 2379] diagram, the voltage of the battery should be tested, and where the test is not satisfactory look for poor cells, and short circuit those that do not come up to voltage. The cells deteriorate through local action rather than through use, so that old cells are more likely to cause trouble than fresh ones. If the trouble is not in the B battery look over the connections, carefully inspecting them for contact and proper position. For example, if the GC is in the plate lead no oscillations can be produced. The condensers used in this work should have the movable section connected to its binding post by means of a flexible lead so that good contact will be certain.

10. When once oscillations are produced note the settings of the condensers and the inductance. Familiarize yourself with the muffled double click and vary the secondary condenser, tapping all the while to see when the oscillations cease. On short wave lengths B battery must be used at a higher voltage and the A battery voltage also will have to be changed. At the longer wave lengths these two may be reduced, although this depends a great deal on the state of the bulb. It has been found that when a bulb has been burned for some time that it will oscillate more freely than when new. The bridging condenser generally need not be varied much from the 0 setting, the capacity due to the

edge effect of the condenser plates being sufficient except when working long wave lengths. The amount of bridging condenser necessary varies greatly with different bulbs. In the appended tables an average bulb was used, so the values given are fairly representative of general conditions. Do *not* use too close coupling between the primary and the secondary circuits for the oscillations will cease with a click as the coupling is increased. In case close coupling is used while trying to get the bulb to oscillate it is doubtful whether the oscillations can be started on account of the large amount of resistance that is added to that of the secondary inductance due to coupling alone. The closest point that can be safely used without the bulb stopping its oscillations can be found by observation.

11. Audibility readings can be taken by placing two pairs of telephones in series in place of the one pair, the audibility box being connected across the pair of telephones on which the readings are to be taken.

#### The Ultraudion Used as a Detector for Spark Signals Only

12. Frequently it is desirable to preserve the distinctive note of a spark transmitter when receiving. The Ultraudion, when in the oscillating condition, changes the spark note to a rough note, the roughness of the note depending on the spark frequency and the amount that the receiving circuit is detuned. Although the Ultraudion is [fol. 2380] in its most sensitive condition when oscillating, yet the note produced is difficult to read under static conditions. If either the stopping or the bridging condenser is varied a point will be found where the distinctive spark is brought in. This point can be found by trial. The oscillations are preferably stopped, or prevented, by keeping the bridging condenser large. The Ultraudion in the non-oscillating condition is at least twenty times as sensitive as the audion detector.

#### The DeForest Amplifone

13. The best place to connect the amplifone is in series with the pair of telephones of the ultraudion circuit. It has been found that one step of amplification is all that can generally be used. Although greater increase can be obtained with two and three steps the corresponding increase

of amplifier noises and static is so great as to more than counterbalance the increase of signals.

14. The binding posts marked  $S_1$   $S_2$  are the connecting points for the amplifone. Connect one post  $S_1$  directly to one of the telephone binding posts of the ultraudion and connect from the other telephone post through the telephones to the  $S_2$  post. A description of the amplifone and its operation was issued by the Department, September 30, 1914. Audibilities can be taken of the amplified signals by connecting the audibility box across the telephones of the amplifone.

#### The Telephone Transformer

15. The telephone transformer is used primarily to reduce interference from arc stations operating on about the wave length that is being received. When using this transformer a station can be read when the wave length is only 6% off the interfering wave length. This applies to arc signals. The gain in selectivity is not so great when a spark station is being received. It also helps in reducing static disturbances as the coupling of the transformer can be varied and, although the loudness of the signals is decreased, the static is generally so considerably decreased that signals can be read without the transformer would be too much broken up to read.

16. The transformer (see Figure 2) consists of a primary and a secondary. The primary has a low resistance and will need to be connected in series with the telephones of the ultraudion circuit, that is, the telephones and the primary take the place of the ordinary receiving telephones of the circuit. The secondary of the transformer is tuned roughly by means of a tuning condenser  $C$  of from 0.01 to [fol. 2381] 0.10 mfd., capacity placed in series with the secondary of the transformer. This condenser can be a mica dielectric condenser which is variable (x) by 0.01 mfd. steps. The telephones are connected across this capacity with a condenser  $C_1$  in series with them. The series condenser can be from 0.005 to 0.02 mfd., and variable  $\gamma$  0.005

(x) If variable condensers are not to be had, making  $C$  about 0.01 mf. and  $C_1$  0.02 mf. will tune the circuit for receiving a tone of about 1,000 vibrations per second.

mfd. steps. The two coils slide on an iron wire core so that the coupling can be varied.

#### Specifications of the Transformer.

17. Primary spool:—Core is made of fiber tube that is 1 inch inside diameter,  $2\frac{1}{2}$  inches long. Heads are  $\frac{1}{4}$  inch thick and  $3\frac{1}{2}$  inches in diameter. Distance between heads is 2 inches. Wind 40 layers of  $\approx 28$  B&S SCC wire. Bring out the beginning and the end of the winding for connection.

18. Secondary spool:—Core is made of fiber tube that is 1 inch inside diameter,  $3\frac{1}{2}$  inches long. Heads are  $\frac{1}{4}$  inch thick and  $2\frac{1}{4}$  inches in diameter. Distance between heads is 3 inches. Wind 18 layers of  $\approx 26$  B&S SCC wire. Bring out the beginning and the end of the winding for connection. The resistance of the coil is about 50 ohms.

19. Core:—8 inches long and of such a diameter as to allow the two coils to slide easily over it. Iron wire or silicon-steel strips are satisfactory for this core.

#### Method of Using the D. C. Lighting As a Substitute for the B battery of the Audion

20. The drawback in the use of the ordinary D.C. supply for audion work lies in the fact that the noises of commutation drown out weak signals and otherwise interfere with the reception of signals. These noises can be overcome, for the most part, by means of suitable chokes inserted in the two leads of the D.C. supply. Since the B battery is the chief cause of audion trouble and failure to operate a method of using the D.C. supply has been worked out. Construct the two choke coils in the following manner:

21. The cores are made of fiber tubing  $1\frac{1}{4}$  inches outside diameter with  $\frac{1}{8}$  inch walls and 3-15 16 inches long. The heads are  $\frac{1}{4}$  inch thick and  $3\frac{1}{2}$  inches in diameter. [fol. 23-2] Fasten two heads to each of the cores, thus making two spools that have a winding space of 3-7 16 inches. On each spool wind 32 layers of  $\approx 23$  B&S DCC copper wire. The layers average 112 turns, making 3600 turns on each coil. The resistance of the coils is 43 ohms apiece. Bring out the beginning and the end of the connections. Mount the spools when wound on a closed iron core that has a square section and a square shape. In this manner the inductance,

or the choking effect, will be increased without an excessive amount of wire being used.

22. Connect the chokes, one in each leg of the D.C. circuit, so that the choking effect will be equalized. Connect the potentiometer across the chokes. The potentiometer should be able to carry  $\frac{3}{4}$  amperes and give a voltage range of at least 30 volts. The low voltage connections of the potentiometer are connected, one side to the B-binding post of the audion box while the other is connected to the R binding post. Of course, battery B will have to be entirely disconnected from the circuit when the D.C. is being used. The chokes should be connected so that they help each other in magnetizing the core. If the magnetism of the core is weak and one pole is dead the coils are opposing. When the poles are all equally strong the coils are helping and the magnetism is strong.

## Tables of the Ranges of the 1 P 76 Receivers of the U. S. Navy

23

## 1 P 76 1912 Model.

Lowest number of secondary turns for oscillations is 80.

Wave lengths 700 to 1050 meters.

C from 0° to 15°.

GC from 15° to 40°.

BC at 0°.

160 turns.

Wave lengths 1200 to 1700 meters.

C from 0° to 15°.

GC from 20° to 40°.

BC at 0°.

320 turns.

Wave lengths 2800 to 3100 meters.

C from 0° to 20°.

GC from 15° to 40°.

BC from 0° to 10°.

## 1 P 76 1912 Improved

Lowest number of secondary turns for oscillations is 80.

Wave lengths 500 to 900 meters.

C from 0° to 30°.

GC from 15° to 40°.

BC at 0°.

160 turns.

Wave lengths 850 to 1850 meters.

C from 0° to 60°.

GC from 30° to 50°.

BC at 0°.

320 turns.

Wave lengths 1250 to 2000 meters.

C from 0° to 60°.

GC from 20° to 40°.

BC from 0° to 10°.

[ed. 2383]

Constants for raising to 5000 meter wave length by means of inductance; secondary 14<sup>1</sup>/<sub>2</sub> of the tuning condenser with 320 turns cut in and a 5.0 milli-henry loading coil in series with it.

Primary circuit: All the inductance of the set and 2 milli-henries in series with the primary circuit. Raising to 5000 meter wave length by means of parallel capacity in the antenna circuit. About 110<sup>1</sup>/<sub>2</sub> of the 0.001 mfd. parallel condenser. With the 5.0 milli-henry coil the secondary will oscillate over the entire range of the capacity of the tuning condenser. Wave lengths are from 2500 to 6400 meters. GC from 15° to 20°.  
BC from 20° to 35°.

Constants for raising to 5000 meter wave length by means of inductance; secondary condenser can be used from 9° to 100° when a 5.0 milli-henry loading coil is cut in series with the 320 turns of the secondary. Wave lengths are from 1800 to 6000 meters. GC 15° to 30°. BC 80° for maximum on the long waves. primary circuit with 2 milli-henry loading coil will tune in 5000 meters. By means of a parallel primary capacity use all the primary coupling coil and 40 turns of the loading coil of the set and about 130° of the 0.001 microfarad capacity. With 8 milli-henries of primary load in addition to the entire primary and a series 0.001 microfarad capacity cut in to 135° strong signals and sharp resonance points can be obtained.

Note: When a series condenser in the antenna circuit is used and the antenna loaded with inductance to produce a stiff circuit the resonance point of the primary and the secondary circuits is found by means of a sharp click as the resonance point is passed in either of the two circuits. This is especially true when the longer wave lengths are being used. On the shorter wave lengths a buzz or a click is sometimes heard although it is not always dependable.

## 1 P 76 1914 Model.

## Short wave secondary

Turns	Wave Lengths	C	GC	BC
30	600-1400	0 - 70°	10°	0°
40	750-1900	0 - 100	15	15
50	800-2100	0 - 80	15	20
60	900-2400	0 - 80	15	25
70	1000-2600	0 - 80	15	25
80	1150-2800	0 - 80	15	25
90	1300-3000	0 - 90	15	25
100	1460-3500	0 - 100	15	25

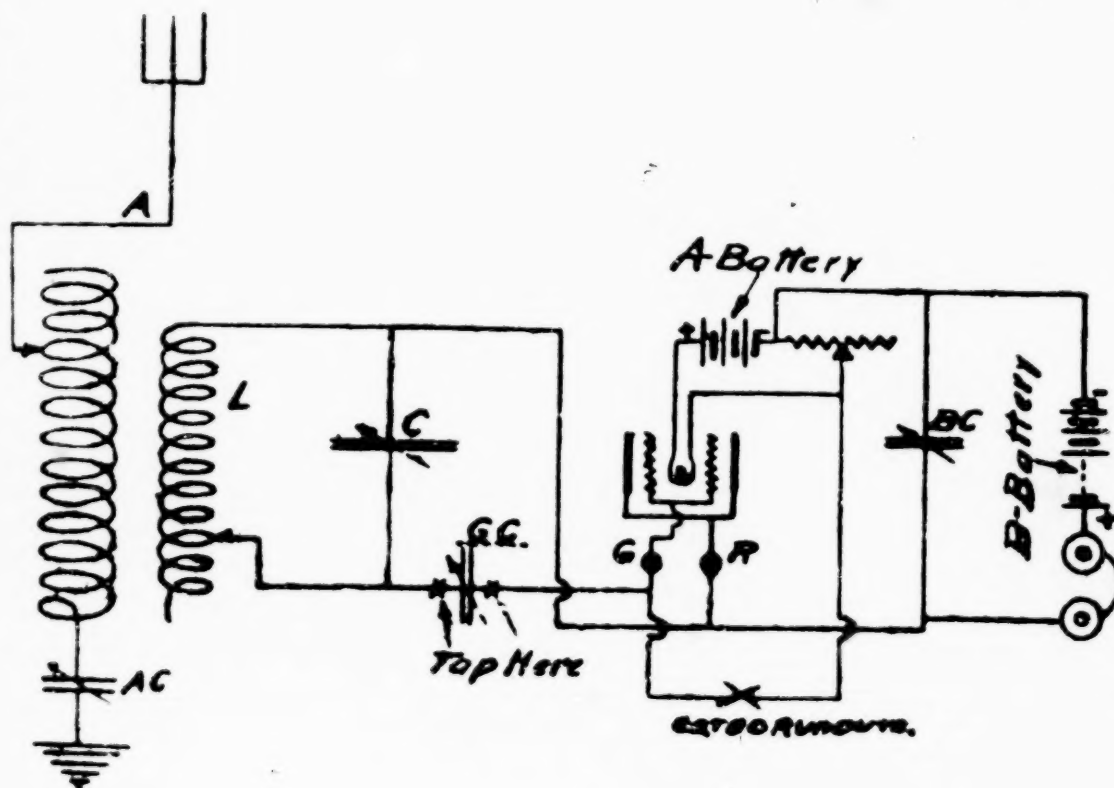
## 1 P 76 1914 Model.

## Long wave secondary

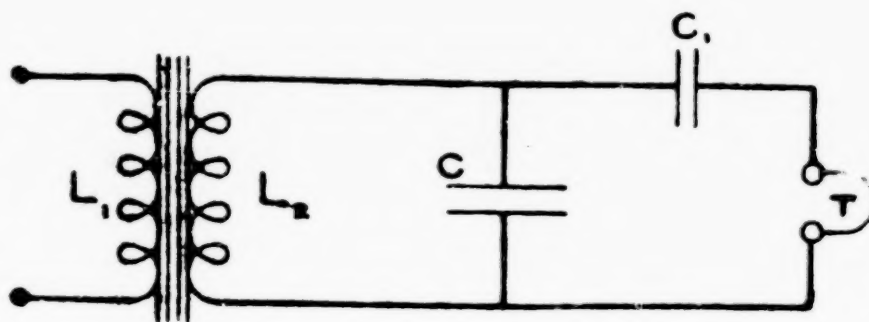
Turns	Wave Lengths	C	GC	BC
20	900-2700	0 - 80	25	15
30	1650-3500	0 - 80	15	35
40	2000-4500	0 - 80	15	30
50	2200-5300	0 - 80	15	30
60	2500-6000	0 - 80	20	20
70	2700-6750	0 - 80	20	20
80	2900-7200	0 - 80	20	20
90	3150-8000	0 - 80	20	20
100	3250-8400	0 - 80	20	20

RE3A101A

sheet 8 of 10



**FIG. 1**  
**ULTRAUDION CIRCUIT**



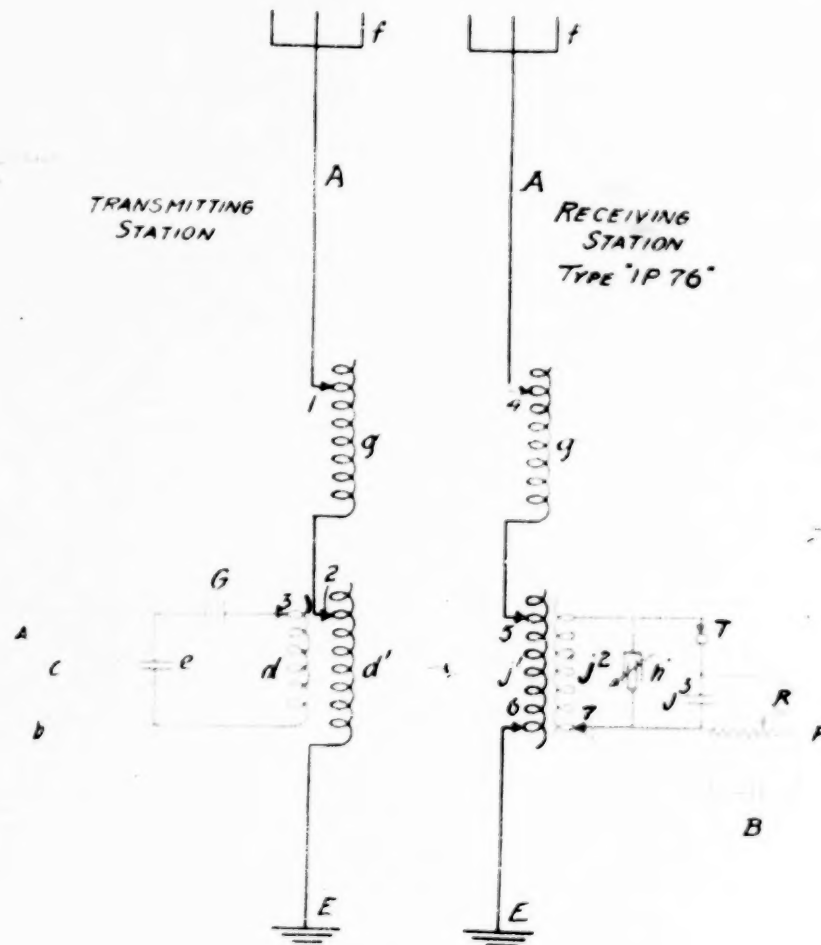
**FIG.2**  
**TELEPHONE TRANSFORMER**

**RES A101A**

**SHEET 10 OF 10**

Plaintiff's Exhibit 87

WIRELESS SPECIALTY APPARATUS TYPE



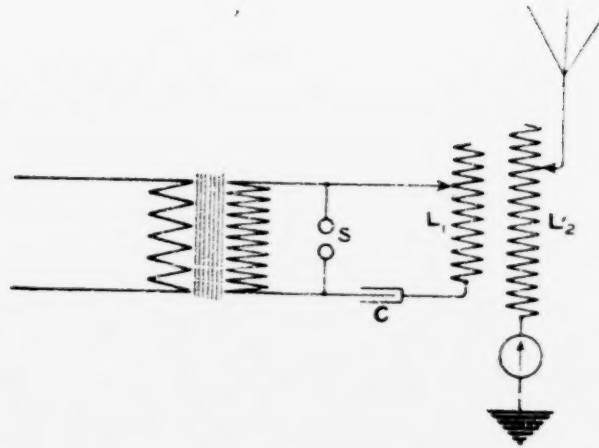


FIG. 36

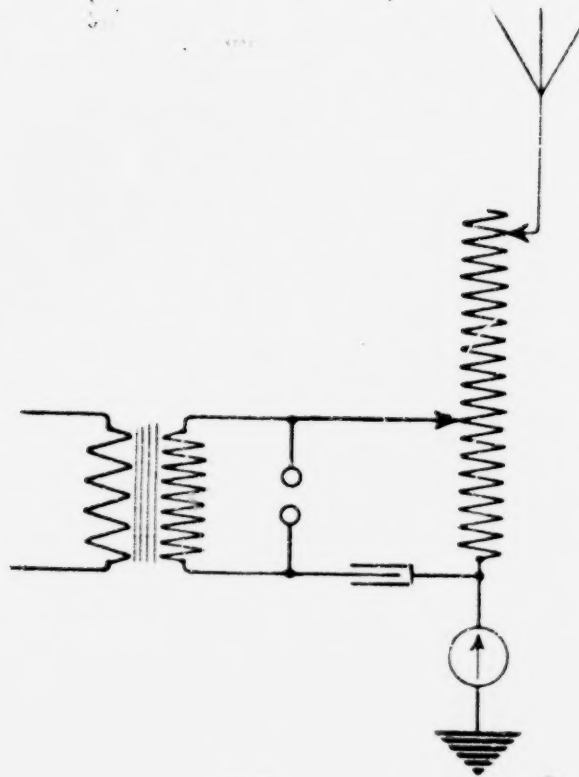


FIG. 37

MAINIEFF'S EXHIBIT 92

## RADIOTELEGRAPHY.

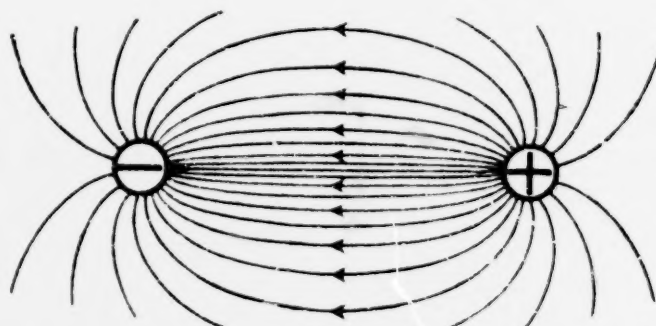


FIG. 1

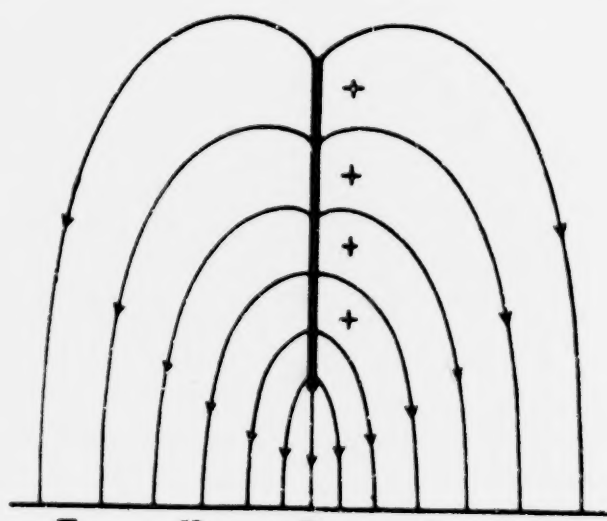


FIG. 2.

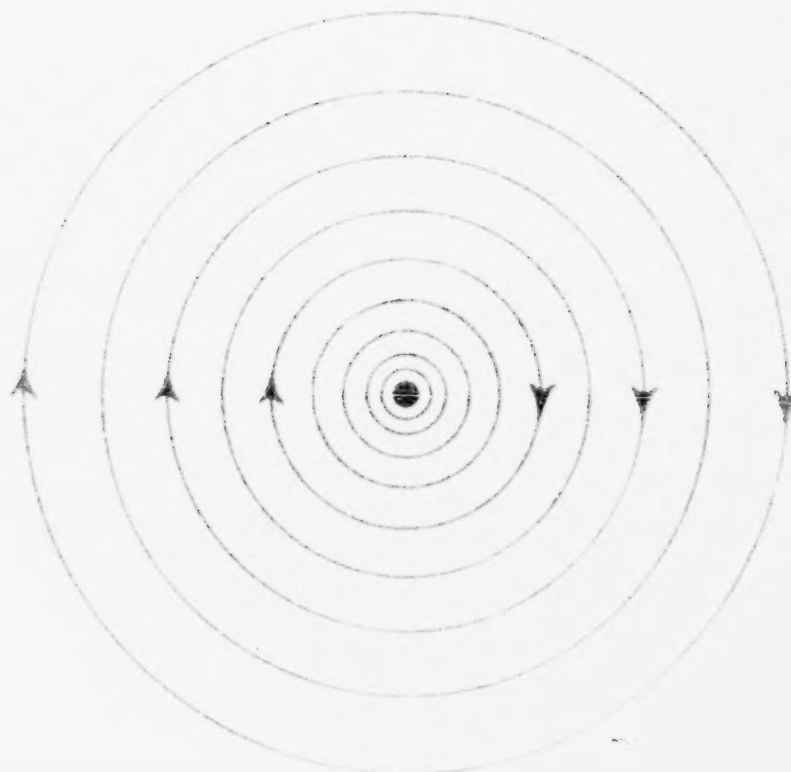


FIG. 4

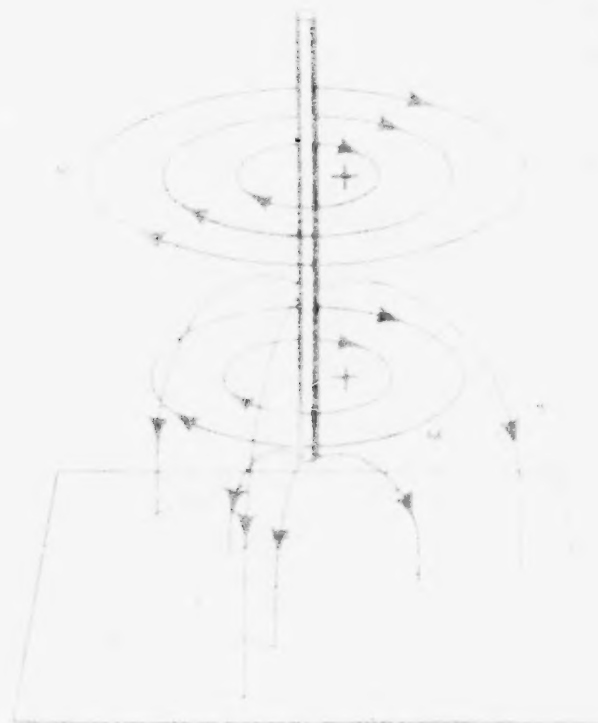


FIG. 5

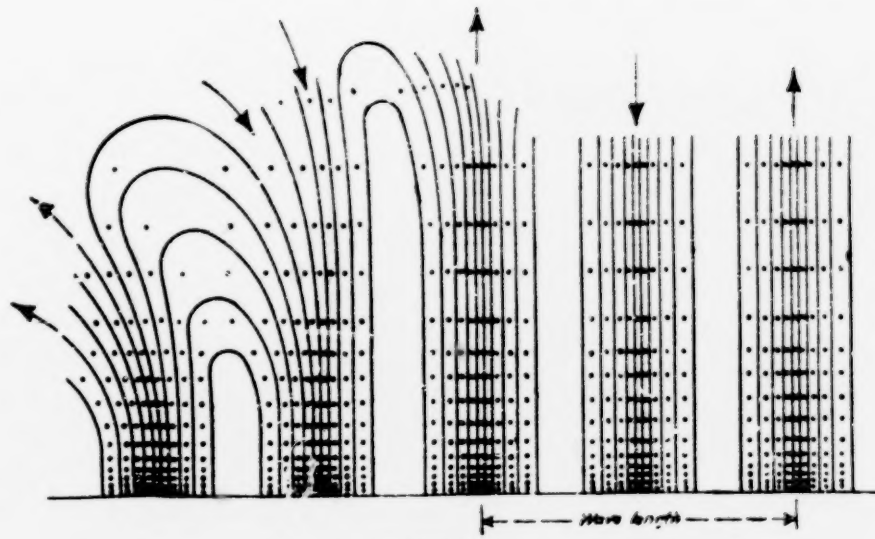


FIG. 9.

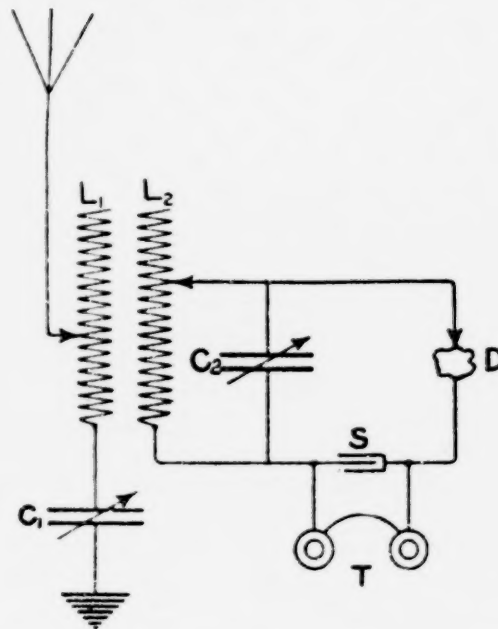


FIG. 10.

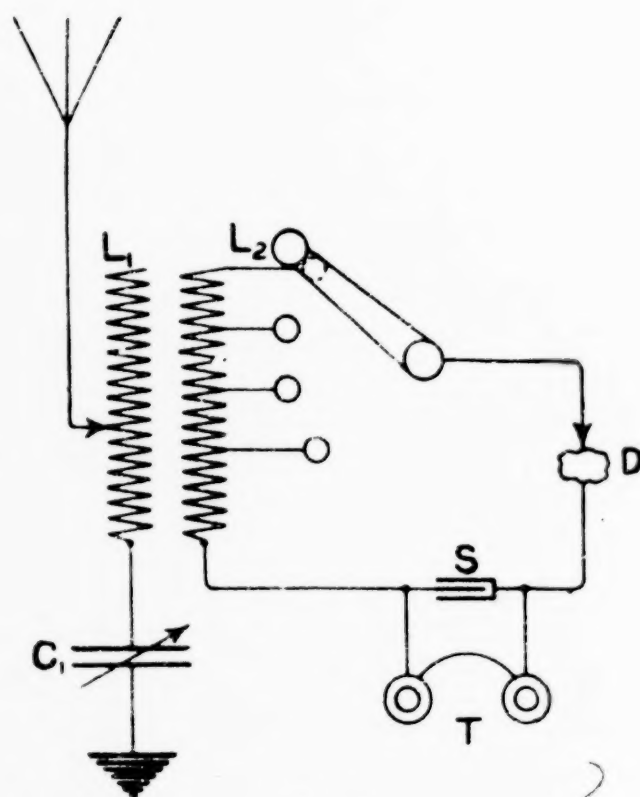


FIG. C1

faces are corroded or pitted, but that when kept air tight they are worn smooth and clean by the sparking action. Sometimes, if there is a flaw in one of the plates or if air leaks into the gap, there will be a noticeable drop in the antenna current, and the note will become poor. When it is believed that the trouble is confined to one or two gaps it is possible to continue sending without dismounting the whole gap by short-circuiting the bad gaps by means of clips provided for the purpose, in which case as many new gaps must be put into circuit by adjusting the movable clip to the right as were cut out by the short-circuiting clips.

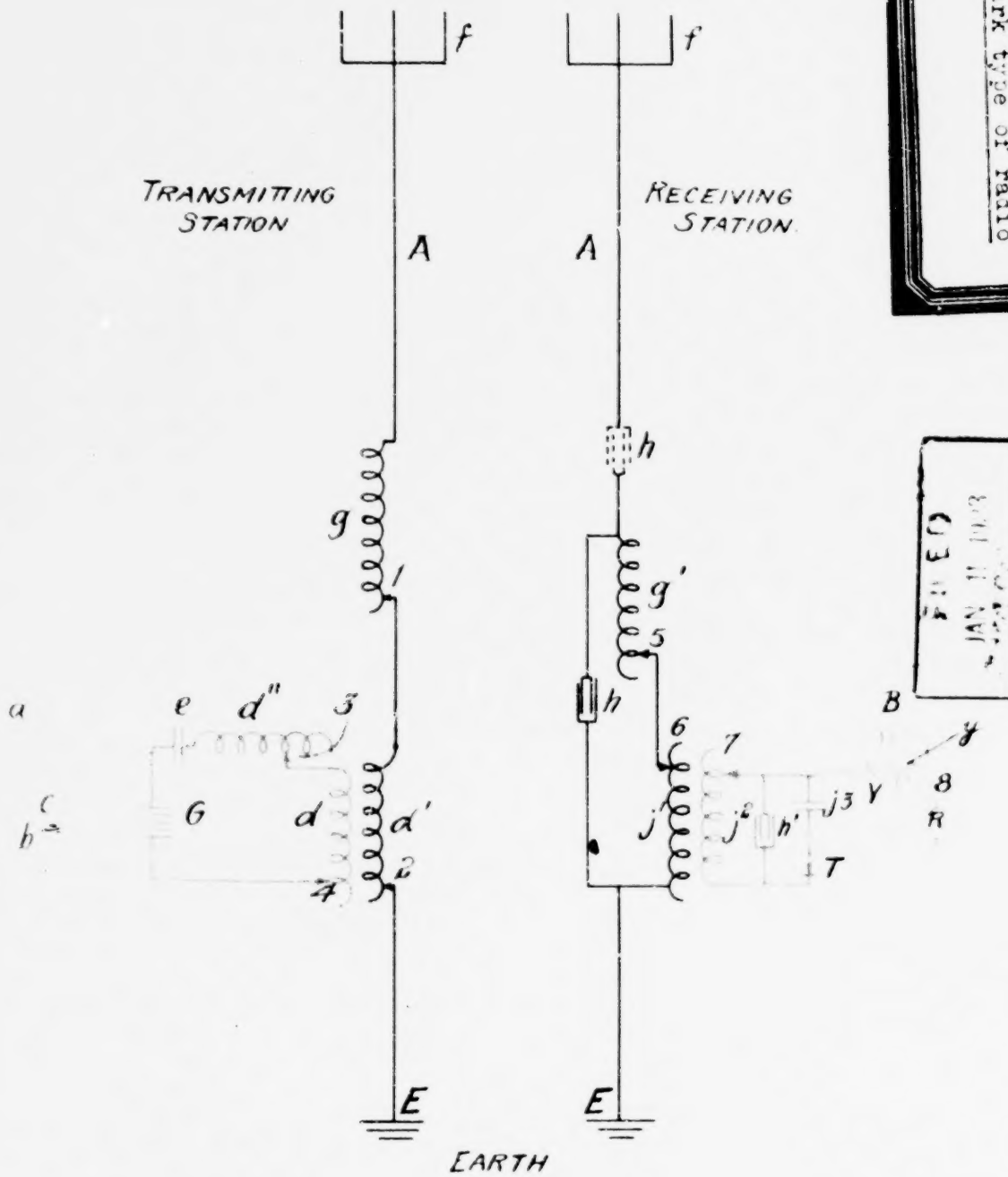
The gap should be dismounted *only* when the trouble has been located in the gap and it has been found impossible to remedy it by short-circuiting the different gaps in use. The gap should be dismounted only by an experienced man, who should clean the *spark* faces by rubbing them face down on fine emery cloth or paper on a *flat* surface. It is absolutely necessary that both the bearing surface and the sparking surface be kept true and plane, as shown by a straightedge.

Great care should be exercised in reassembling the gap to set the mica washers accurately on the annular surfaces of the disk and to put on enough tension with the clamping screws to render all of the gap spaces air-tight.

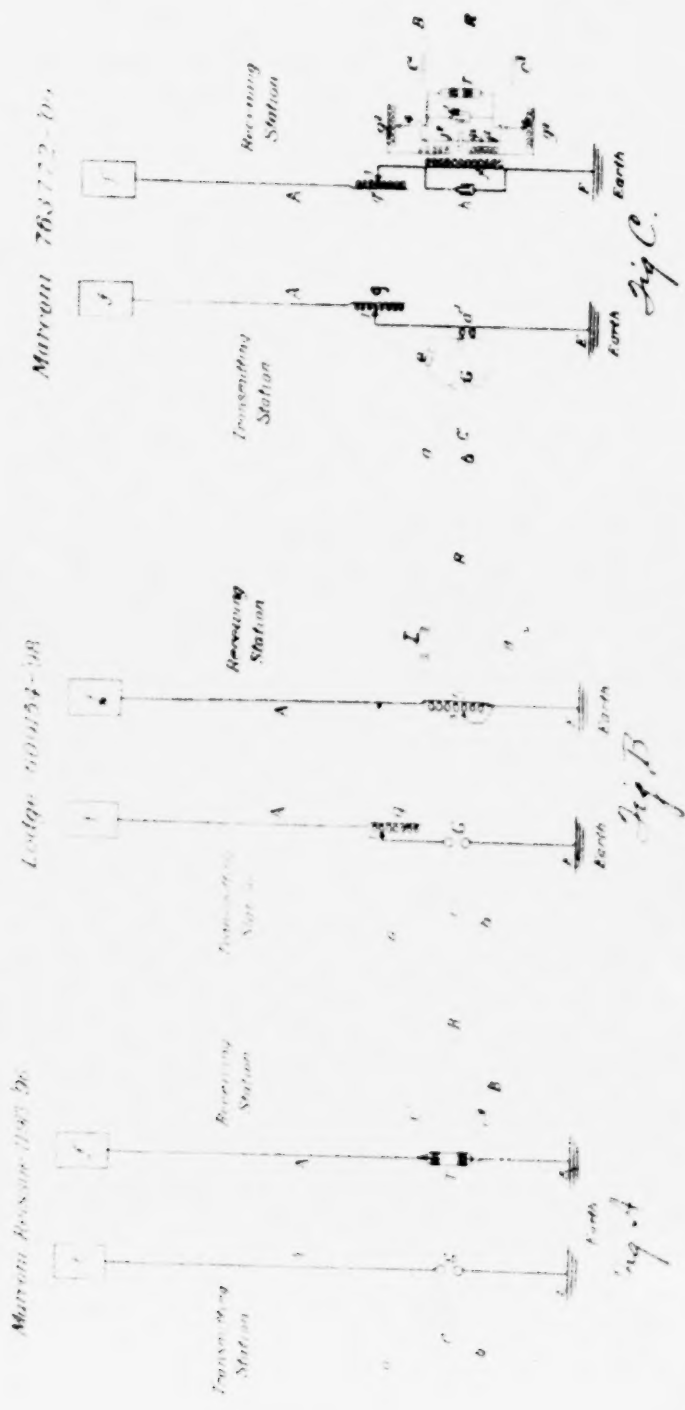
#### TUNING OF SENDING SET.

The tuning of the closed and open circuits to resonance, and the determination of the correct coupling between them are the two most important adjustments in a quenched spark transmitter. In the present type of directly coupled set with a flat spiral as the oscillation transformer, these adjustments can be made either with or without the help of a wave meter. If made without the meter the adjustments are more difficult and must be found by trial, but they should satisfy the following tests: (1) The number of turns in the closed circuit should be chosen so as to give the desired wave length; (2) the antenna hot-wire ammeter should show the maximum reading that can be obtained by adjusting the number of turns in the open circuit according to the table on page 114; and (3) the note as heard in the telephones of the receiving set should be clear and characteristic of spark codes. These adjustments are, in general, dependent on one another, an incorrect change in one usually affecting all the others, but when changed *properly* will be in accordance with the desired wave length, *resonance* of the antenna circuit, and the *desired* coupling with the receiving set. Although the *best* results are obtained

Plaintiff's Exhibit #95, Drawing  
Kilbourne & Clark type of radio  
Apparatus.



Plaintiff's Exhibit 99



PLAINTIFF'S EXHIBIT NO. ~~99~~ (2)

Attest: Dec. 7, 1912 Transmitting Circuits (Table page 4)

Tunes 2, 4

Tunes 4, 6 and 8

Tune 6

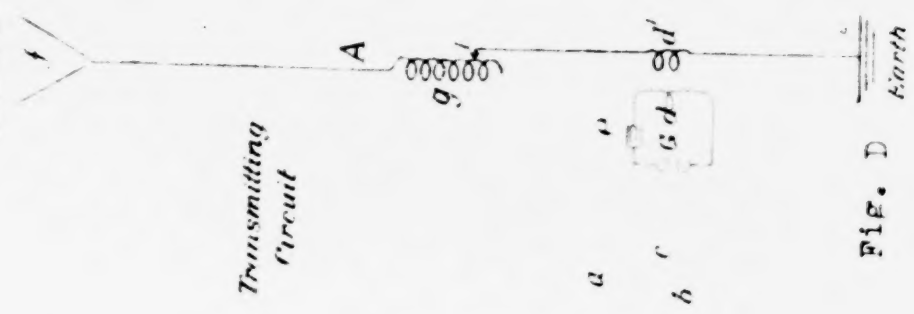


FIG. D

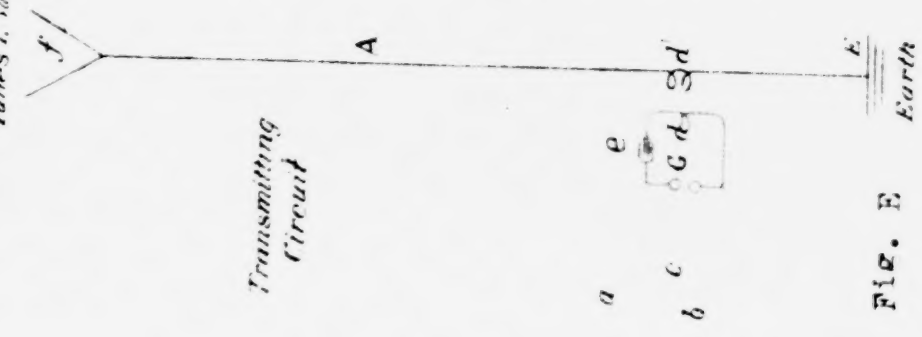


FIG. E

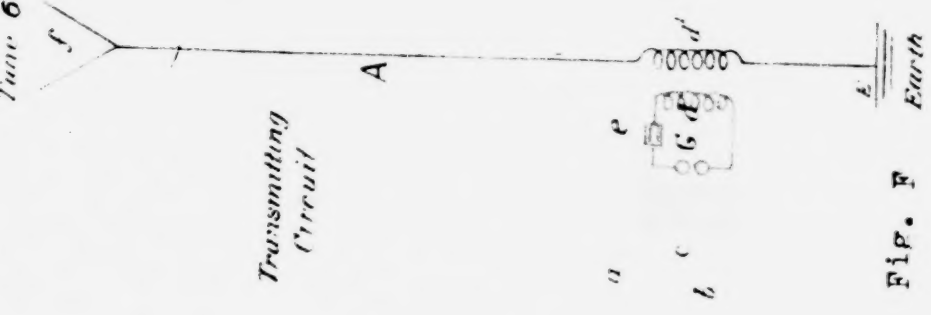
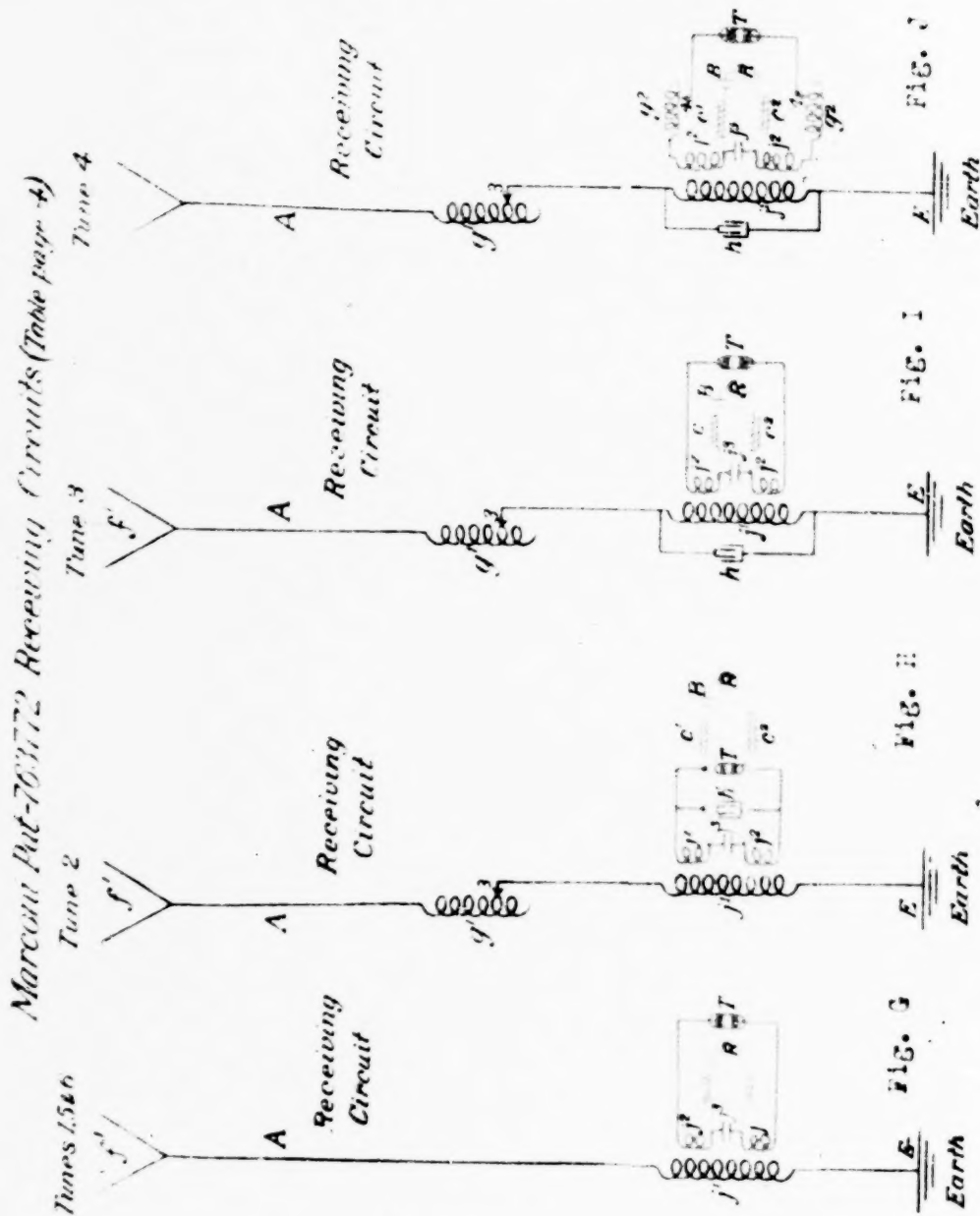
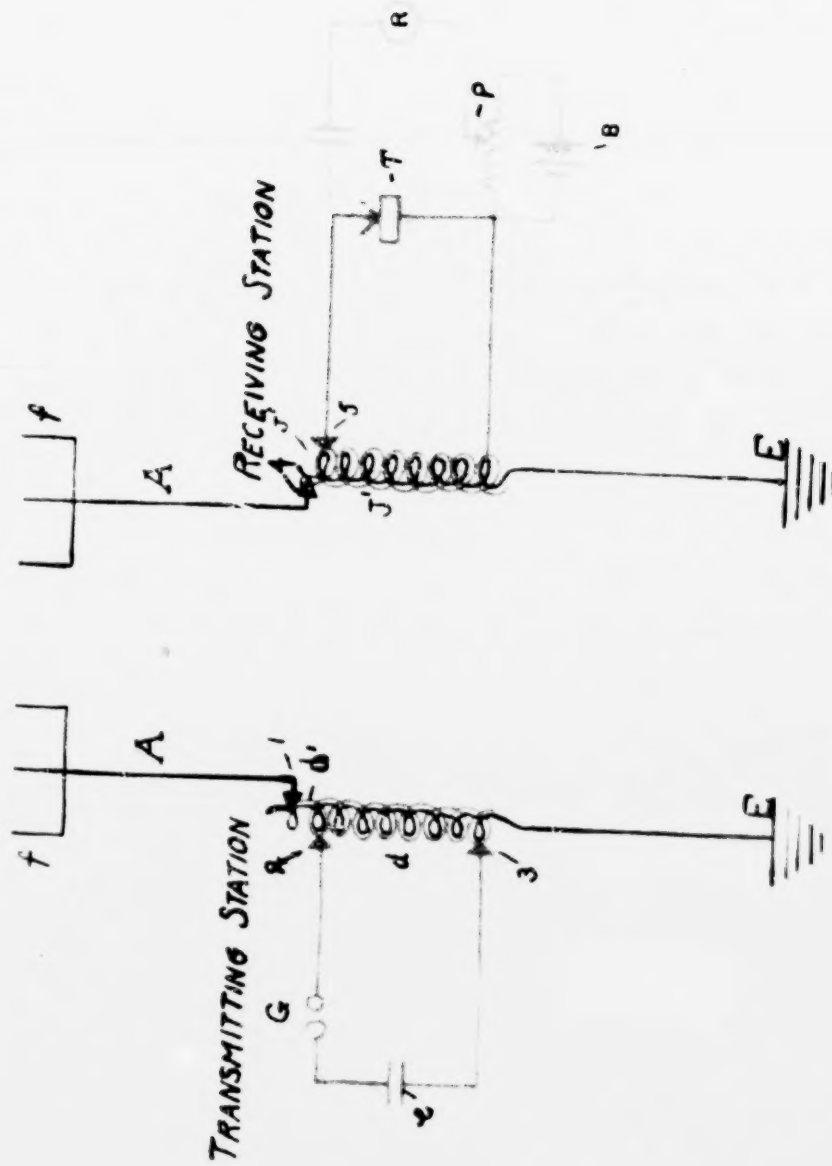


FIG. F

PLAINTIFF'S EXHIBIT NO. ~~8~~ (3)



Plaintiff's Exhibit 102



Waterman Sketch—Foote-Pierson PackSet

[fol. 2408] PLAINTIFF'S EXHIBIT 103

## Signal Corps Bulletin No. 17.

Instructions For Operating The Field Radio Pack Set,  
Model 1912.

The 500-cycle, quenched spark radio transmission set and inductively coupled receiver constituting the 1912 model field radio pack set of the Signal Corps, were adopted after extensive investigation of modern methods in the practice of radio telegraphy. The weight efficiency has been more than doubled without decreasing the effective range of radiation. A brief description of the equipment with instructions for the care and operation of the set follows:

## Drawings

The following drawings will form part of and illustrate this bulletin:

Field radio pack set, model 1912, receiving circuit diagram 911a

Field radio pack set, model 1912, sending circuit diagram 911b

Field radio pack set, model 1912, poles for shelter tent 911c

## Generator

The generator is an 18-pole, alternating current machine of 125 watts capacity at 110 volts and 500 cycles, designed for an armature speed of 3333 R. P. M., the ratio of the gearing being such that this speed is obtained when the crank handles are revolved at 36 R. P. M. A separate direct current exciter is mounted on the main armature shaft for energizing the field magnets.

A double speed clutch is provided on the fly wheel which when properly regulated should engage the armature gear at a speed between 30 and 34 R. P. M. of the crank handles and disengage same when the crank handle speed exceeds 37 R. P. M. Adjustment of the over-speed clutch is made by means of the two radial screws on the periphery of the steel fly wheel which are locked by set screws on the inner face of the wheel; loosening the screws causes the over-speed clutch to operate at a lower speed, and, conversely, tightening this screw causes it to operate at a higher speed.

at each alternation, in which case the fault can be remedied by reducing the number of gaps. If the adjustment is such that the condenser is discharged regularly at every second or third alternation, the note will be even but low pitched, somewhat similar to the note produced by an unquenched spark gap. If the generator speed is constant at 500 cycles, reducing the number of gaps will probably remedy the trouble, although it may be necessary to "loosen" the coupling. By loosening the coupling is meant to reduce the number of turns of the linking spiral (oscillation transformer) common to both the closed and radiating circuits, or, if no common turns are being used, to increase the distance between the sections included in the "closed" and "radiating" circuits.

#### Damping

When the current in the closed oscillating circuit dies out after a few reversals as already described, the oscillations are said to be "damped". The proper amount of damping is indicated by a high pitched, musical note. Damping is aided by close coupling; however, if the coupling is too close, a retransfer of energy from the radiating to the closed oscillating circuit may occur, with an induced E. M. F. sufficient to again break down the spark gap. This condition can be detected by its effect on the note which will be lower pitched and ragged.

The remedy is to loosen the coupling. In tuning sending circuits, the operator may ascertain the character of the note emitted by listening on the telephone of his own receiving set, which while disconnected at the control switch will be sufficiently energized by the field of the sending helix or oscillating transformer to produce the note.

#### Receiving Set

The receiving set consists of an inductively coupled transformer, perikon detector, series and stooping condenser, with terminals, switches, etc., mounted in an oak case with hard rubber top and front and is supplied with a Sullivan type, high resistance, double head telephone receiver, as indicated in drawing 911a.

[fol. 2411] The primary coil of the transformer is wound with 170 turns of No. 22 enameled copper wire divided into two sections, one of 10 turns and one of 160 turns. Each single turn of the small section is tapped off and the leads

connected to the terminals of the dial switch numbered from 1 to 10. The large section is divided into 16 groups of 10 turns each and the leads connected to the terminals of the dial switch marked from 10 to 160. As these dial switches are connected to a common zero point with the switches working in opposite directions from this point, as shown in the diagram, the total number of turns included can readily be determined, being the sum of numbers indicated by the two switch arms.

A condenser of small capacity is connected in series with the aerial and is provided with switch for shunting or short circuiting same when not in use. This condenser is intended for the reception of wave lengths of two hundred meters or less, and is normally short circuited when longer waves are being received.

A small detached buzzer is provided for testing purposes. This buzzer, when operated in the vicinity of the aerial, counterpoise leads, or windings of the coils, excites feeble oscillations which enables the operator to adjust his detector efficiently before tuning the primary and secondary circuits.

#### Tuning of Receiving Set

After adjusting the detector to a sensitive point by the aid of the test buzzer, move the secondary coil into the primary as far as it will go and set the secondary dial switch on, say 200, which will answer for wave lengths between 250 and 700 meters. Then vary the dial switch marked from 10 to 160 until the signals are heard; this will probably be found near the contact marked 60. When the signals are heard, the adjustment is continued by varying the primary and secondary dial switches and the position of the secondary within the primary coil (i. e. the "Coupling", which for wave lengths approximately 400 meters will be between 10 and 20 on the Coupling scale) until the maximum sound is heard in the telephones. If the incoming wave is found to be short the small 2-point condenser switch may be set at the "On" position which places the condenser in series with the aerial.

#### Shelter Tent

This tent is similar in dimensions and construction to the standard "Common" tent issued by the Quartermaster's Department, but is made of lighter duck and is not provided with ridge poles nor uprights. Three extra sections are

[fol. 2412] furnished with each 40 foot mast and it is intended that these will be substituted for the tent ridge and upright poles. Two extension pieces are supplied for adapting one extra section as ridge pole and two wood plugs with spikes are supplied for adapting the other two sections for use as uprights. These are shown in the accompanying sketch together with ridge poles and upright assembled for setting up.

#### Insulating Device

A device is provided for use in insulating the aerial when the shelter tent is used in damp weather, consisting of a square piece of sheet rubber with small marginal holes for lacing into the ventilator at either end of the tent, and a tube attached to the center for admitting the aerial lead. When in use, sufficient slack should be left in the aerial lead to form a drip loop outside of the tent, and if found necessary a piece of heavy insulated wire can be used as a leading in wire.

#### Packing

In packing the set on the pack frame, the fourteen wood tent pins and four extension pieces should be folded in with the shelter tent; the insulating device, iron guy pins, hammers, crank handles and oil can placed in the accessory bag. The gear wheel with its leather case, antennae and counterpoises are carried in the large canvas bag. Two end guys are furnished with each tent, which, in case an extra section of mast is broken, will hold the tent in position without using a ridge pole.

The hand generator, generator stand and ten mast sections are carried on one mule; the operating chest, antenna-counterpoise bag and accessory bag on another. The antenna-counterpoise bag is suspended by the "D" rings on the side of the pack frame provided with one set of hooks. The operating chest is hung on the top set of hooks on the opposite side and the small accessory bag beneath it on the lower set of hooks. The tent is carried on top of the frame between the chest and large bag. Two wood foot rests are supplied with each generator stand with sixteen screws for securing them to the adjustable flanges on the base of the stand.

Office of the Chief Signal Officer of the Army. August 15,  
1912

# FIELD RADIO PACK SET, MODEL 1912

## RECEIVING CIRCUIT DIAGRAM

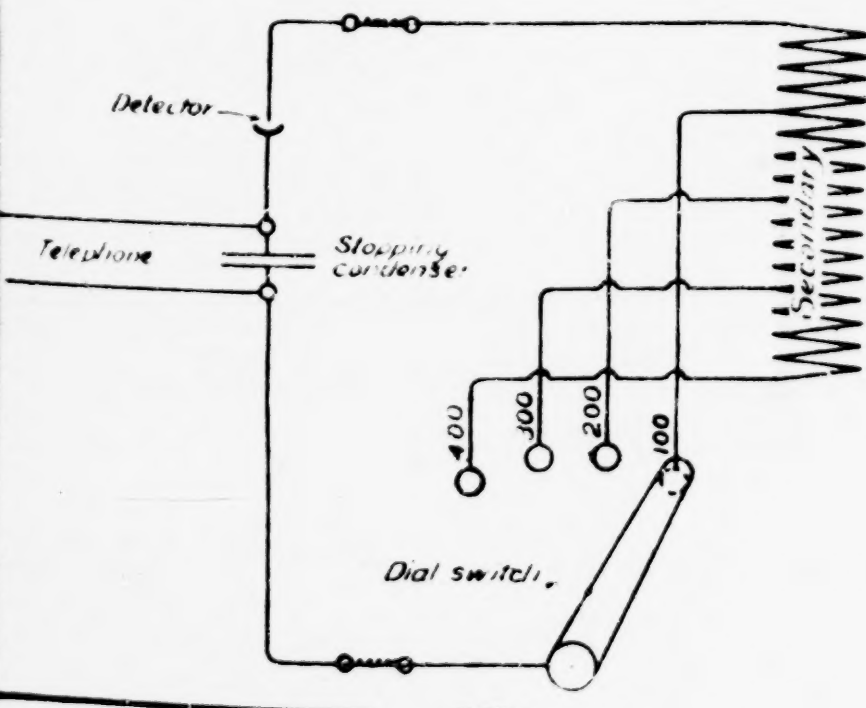
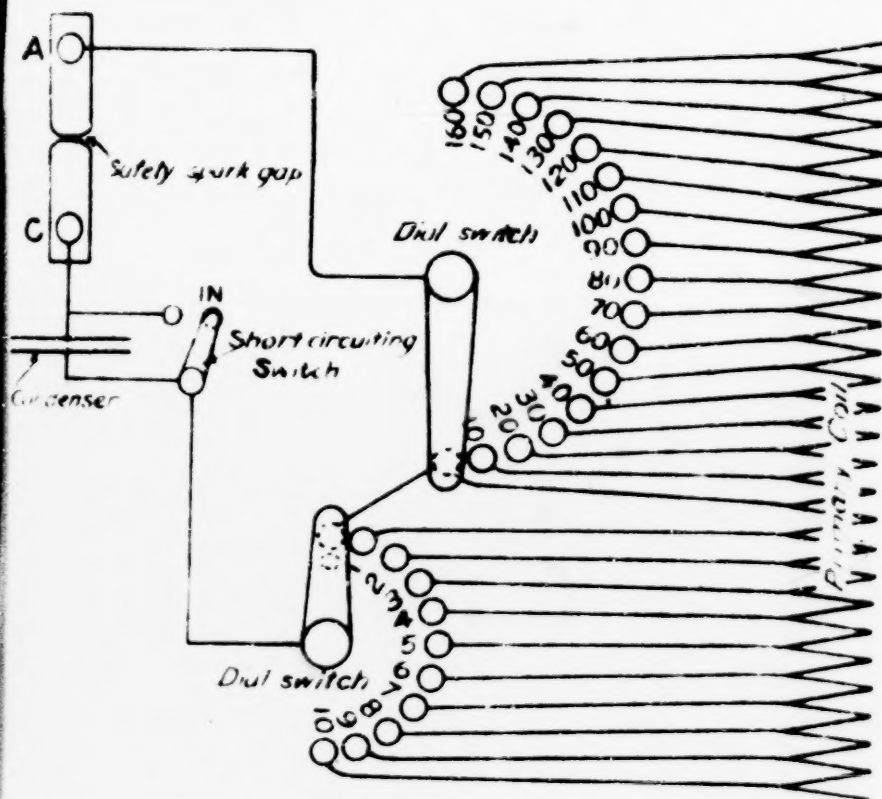
911a-1

SIGNAL CORPS  
U.S. ARMY

Aug. 5, 1912

Ordered	Leed (Amstrad)
Date	J. H. Dyer
Drawn	P. C. Bowen
Checked	<i>[Signature]</i>
O. K.	
Approved	D. O.

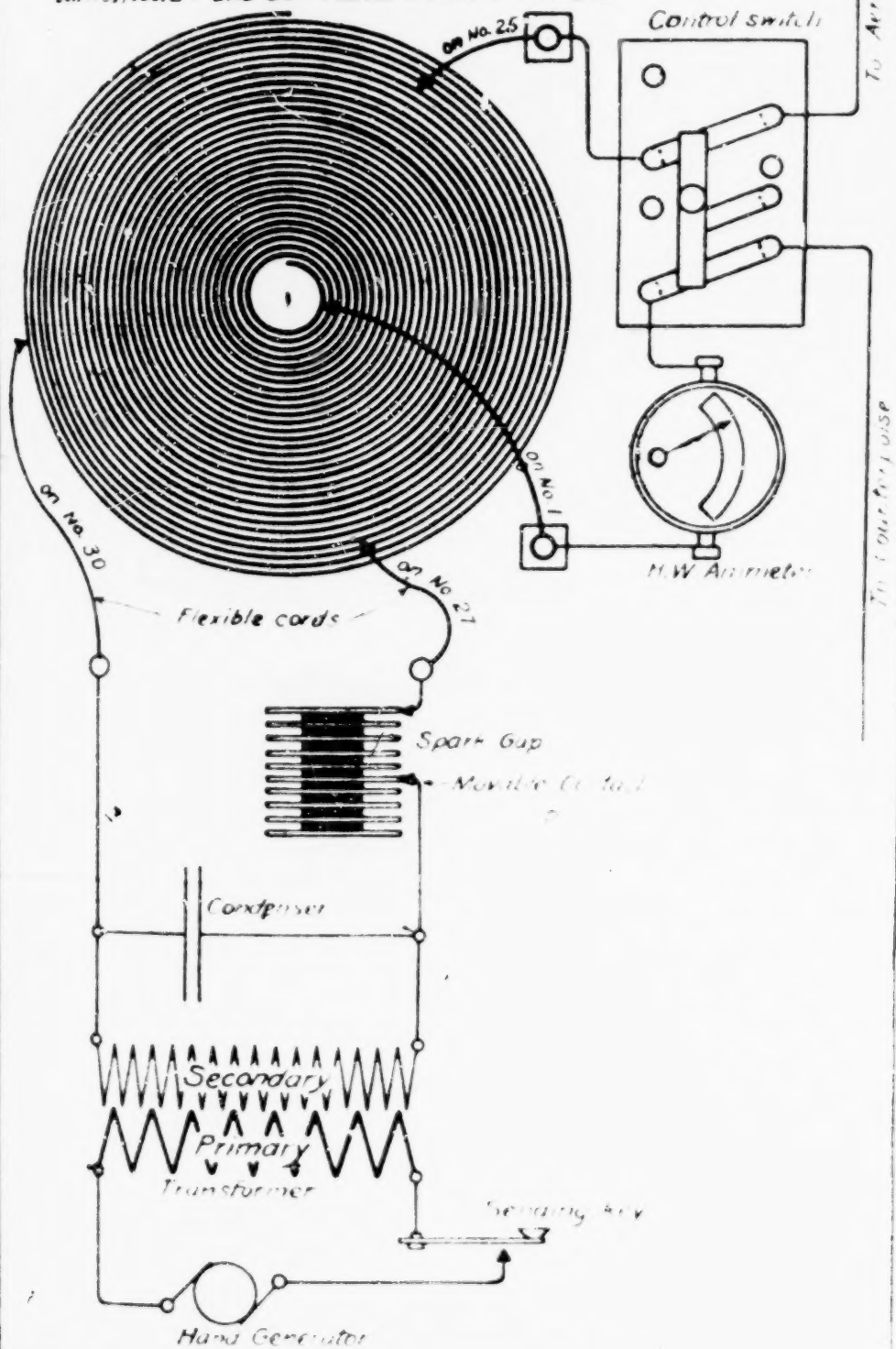
Revised  
Nov. 4 1912. changed  
location of primary con-  
denser



# FIELD RADIO PACK SET, MODEL 1912

## SENDING CIRCUIT DIAGRAM

Oscillating Transformer, 30 turns.  
Closed oscillating contacts on  
turns Nos. 27 and 30—Aerial on Nos. 1 and 25



911b

SIGNAL CORPS  
U.S. ARMY

Aug. 6, 1912

Ordered	1000
Date	10/1
Drawn	10/1
Checked	10/1
C.A.	10/1
Approved	10/1

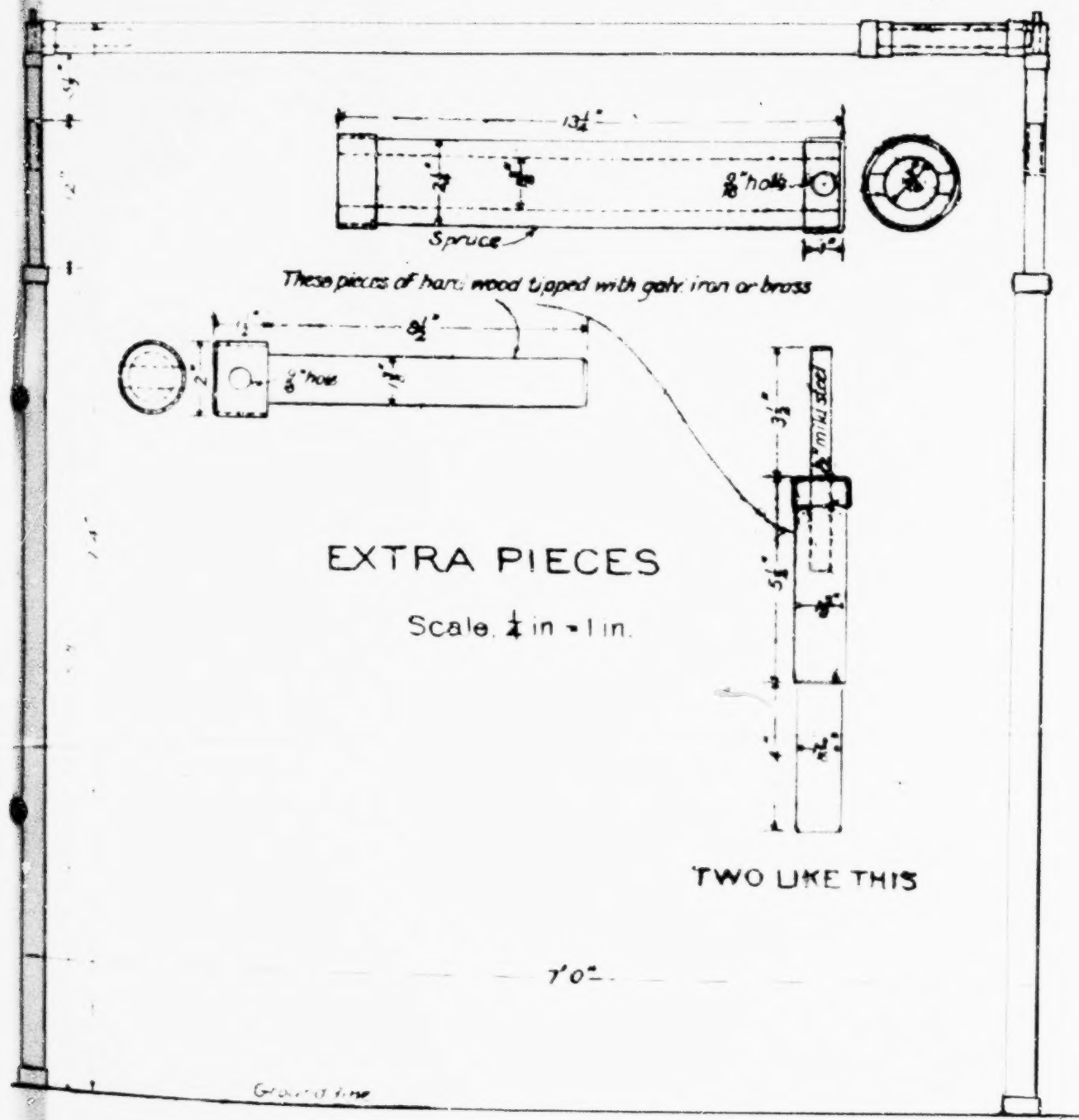
2781

911c

DESIGNED BY	W. S. 1912
APPROVED BY	
DATE	
BY	
FOR	
BY	
FOR	
BY	
FOR	

# FIELD RADIO PACK SET, MODEL 1912. POLES FOR SHELTER TENT

Scale, 1 in. = 1 ft.



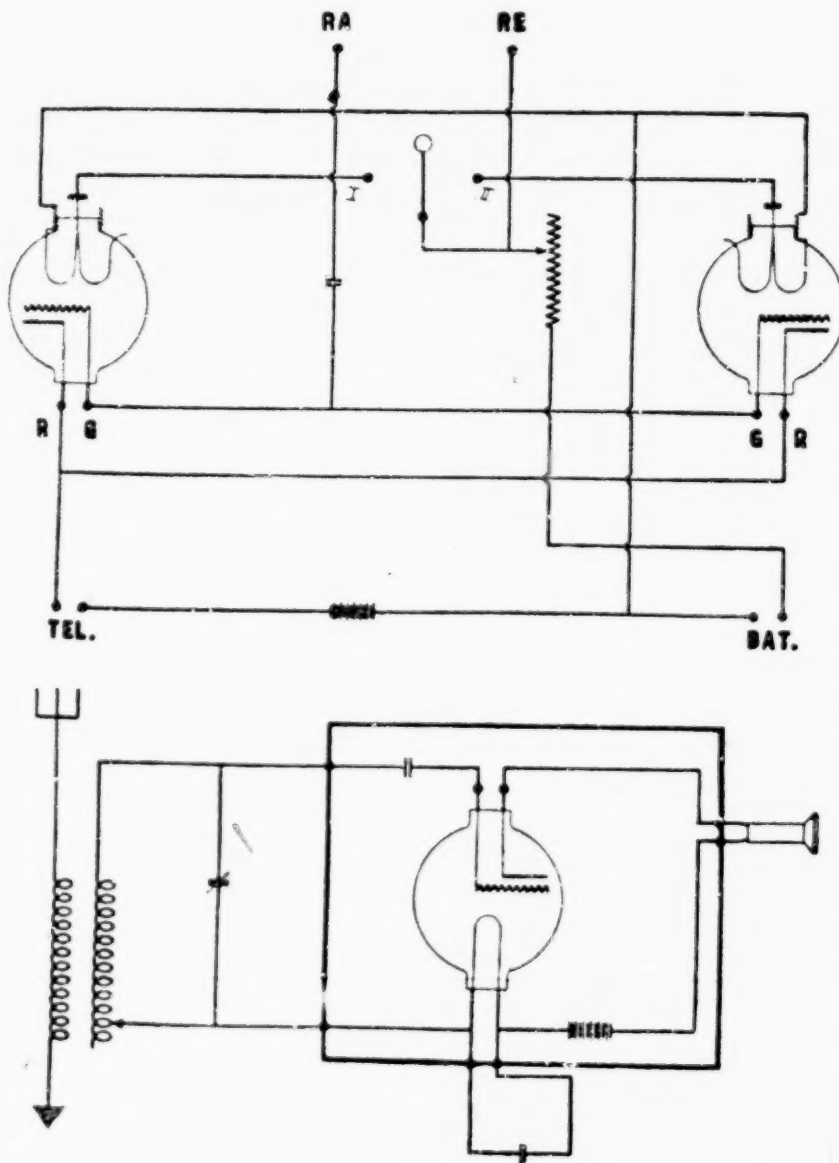
EXTRA PIECES

Scale, 1/4 in. = 1 in.

TWO LIKE THIS

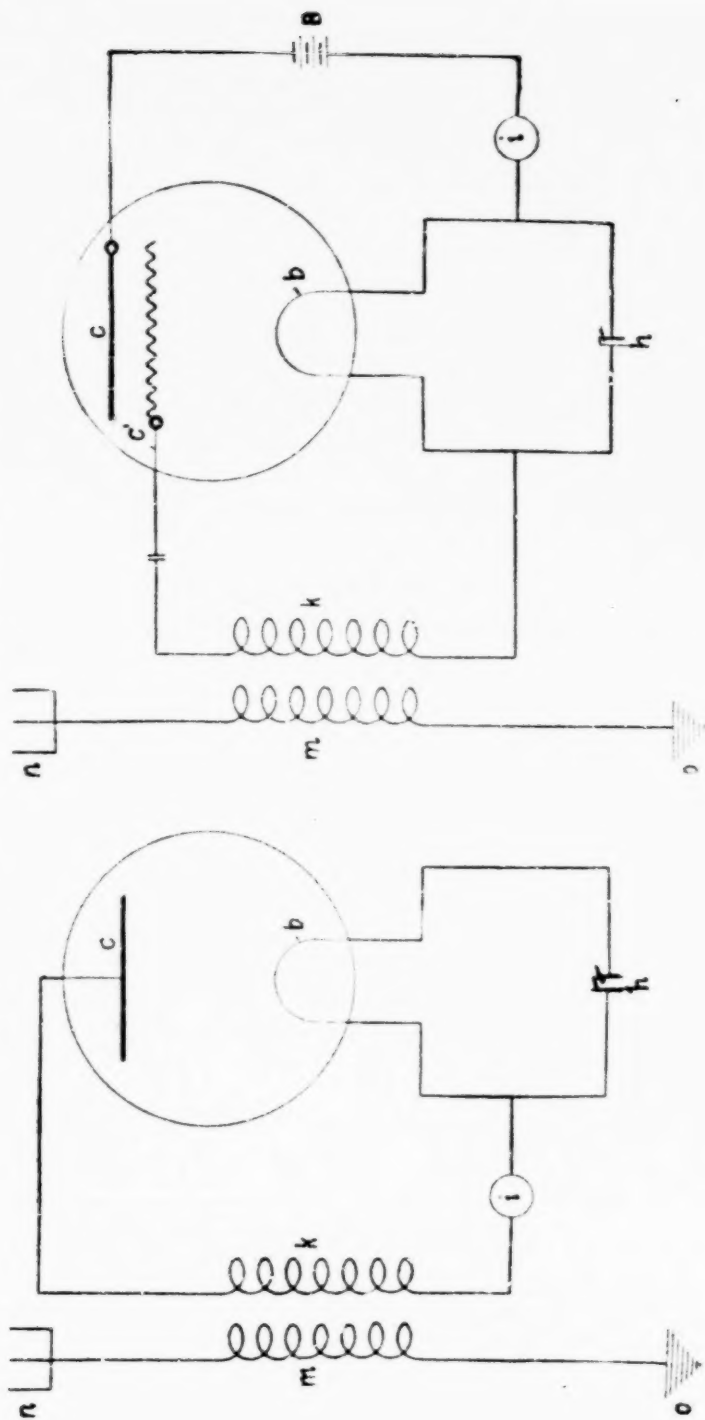
27742

Plaintiff's Exhibit 106



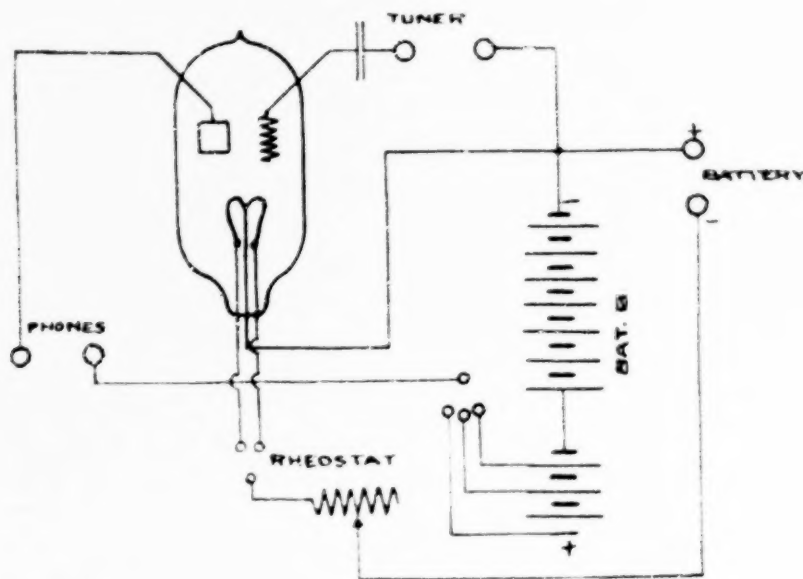
Drawing Simplified Circuits "PN" Detector

Plaintiff's Exhibit 107  
Fleming and DeForest Compared



Plaintiff's Exhibit No. 108

## Circuit of Type RJ4 Audion Detector



After the first filament has been consumed wind the little copper wire tight around the brass base of bulb underneath the rubber band. This connects the second filament

### Instructions.

Do not connect over six volts Storage Battery to the external binding post marked + and -. Before lighting the filament see that the resistance switch is on "ALL IN" position. Then adjust rheostat until lamp burns at normal brightness. Adjust brightness of filament by the Battery B switch to give maximum sensitiveness.

In connecting up the Audion Detector, connect the grid to G and wing to W as marked below the binding posts. The Grid is the zig-zag wire terminal. The Wing is the plate.

If bulb is copped the green wire leads to the grid, the red leads to the wing.

---

**RADIO TELEPHONE & TELEGRAPH COMPANY**

300 BROADWAY, NEW YORK

## Concerning the RJ4 Audion Dectector

---

The Audion has been proven, by scientific and official tests to be from 1.5 to 3 times as sensitive as any crystal detector. With it even in this small and cheap form, telegraphic ranges far greater than those possible with the crystal or electrolytic detectors are easily attained. There is scarcely an amateur who has tried one but will admit this, and consequently has no further use for his crystal detector.

It is reliable, requires no adjustment after the proper voltage and heating currents are determined, it can not be injured by powerful transmitter sparks in the immediate vicinity. If it momentarily loses its sensitiveness by reason of the transmitter spark, it is automatically restored, without the slightest decrease in its sensitiveness.

If too much "Battery B" voltage be applied a blue glow will appear in the bulb, or tube, or may be seen merely around the edges of the "plate" or wing. When this blue glow fills the bulb it is usually not very sensitive, and can be removed by simply reducing the B voltage by the 4 point switch on front of box. The sensitiveness can be instantly restored by merely switching off and on the lighting current. Only one filament should be burned at one time. This doubles the life of the bulb.

**Never burn the filament at excessive brilliancy,** as full sensitiveness can be obtained at normal brilliancy.

Always use a storage battery for lighting the lamp, as dry cells run down very quickly when used for that purpose.

**Never use more than three cells of storage battery.**

Don't let the storage cells run down low and then hook in another fourth cell, because if this is done there is always danger of the run-down cells picking up, or recuperating after a short period of rest and then of burning out the filament when first switched on again.

Connect the secondary of the receiver tuning circuit to the binding posts marked "Tuner."

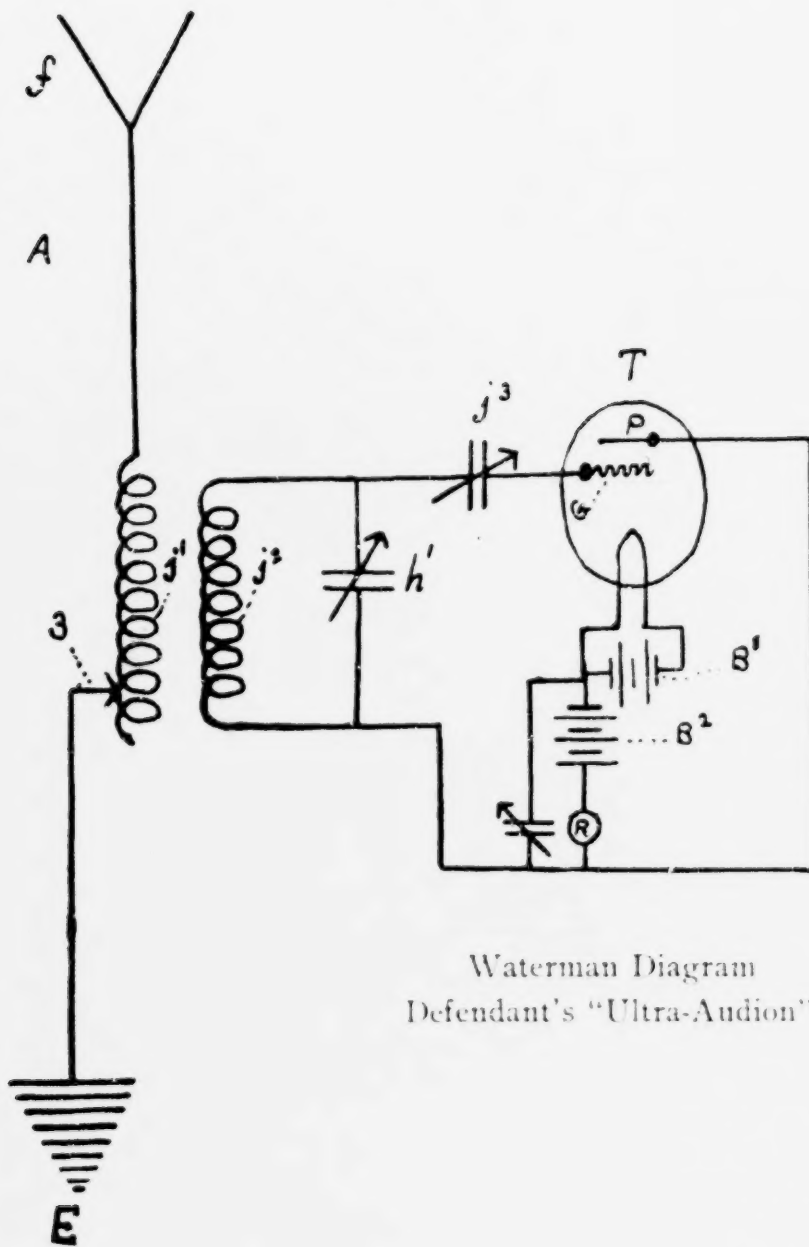
It makes some difference in the results obtained which of these two terminals is connected to one or the other of the two "Tuner" binding posts. The surest way of determining this is to reverse the two connections, and thus observe which gives the louder signals.

(The RJ4 Audion set is for **Amateur** work only. It is not under any conditions licensed to be used for commercial work.)

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**RADIO TELEPHONE & TELEGRAPH COMPANY**

309 BROADWAY, NEW YORK



Waterman Diagram  
Defendant's "Ultra-Audion"

## Plaintiff's Exhibit 110

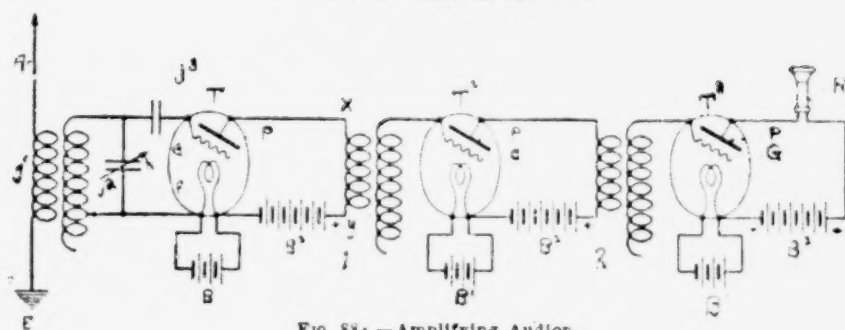
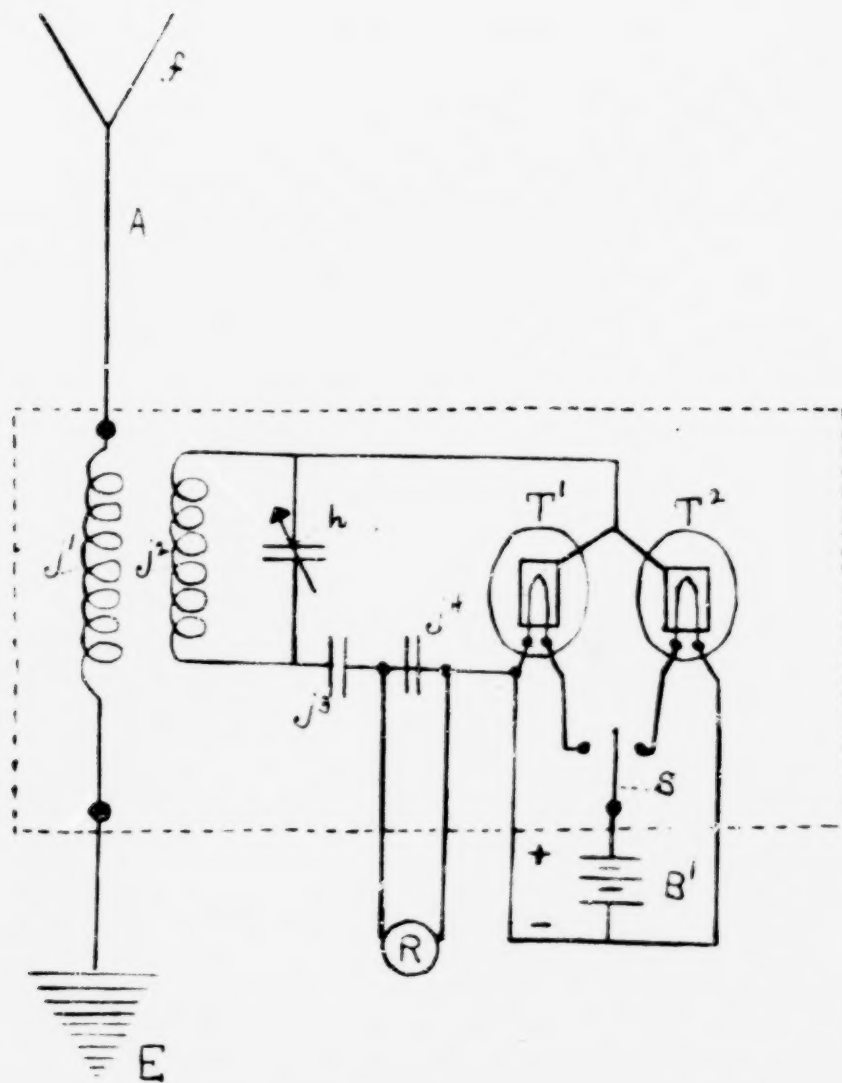


FIG. 88a — Amplifying Audion  
(U.S. PAT. NO. 1,015, 1915)

## Plaintiff's Exhibit 111



Waterman Sketch Circuits of Plaintiff's Exhibit 28  
Fleming Valve Receiver

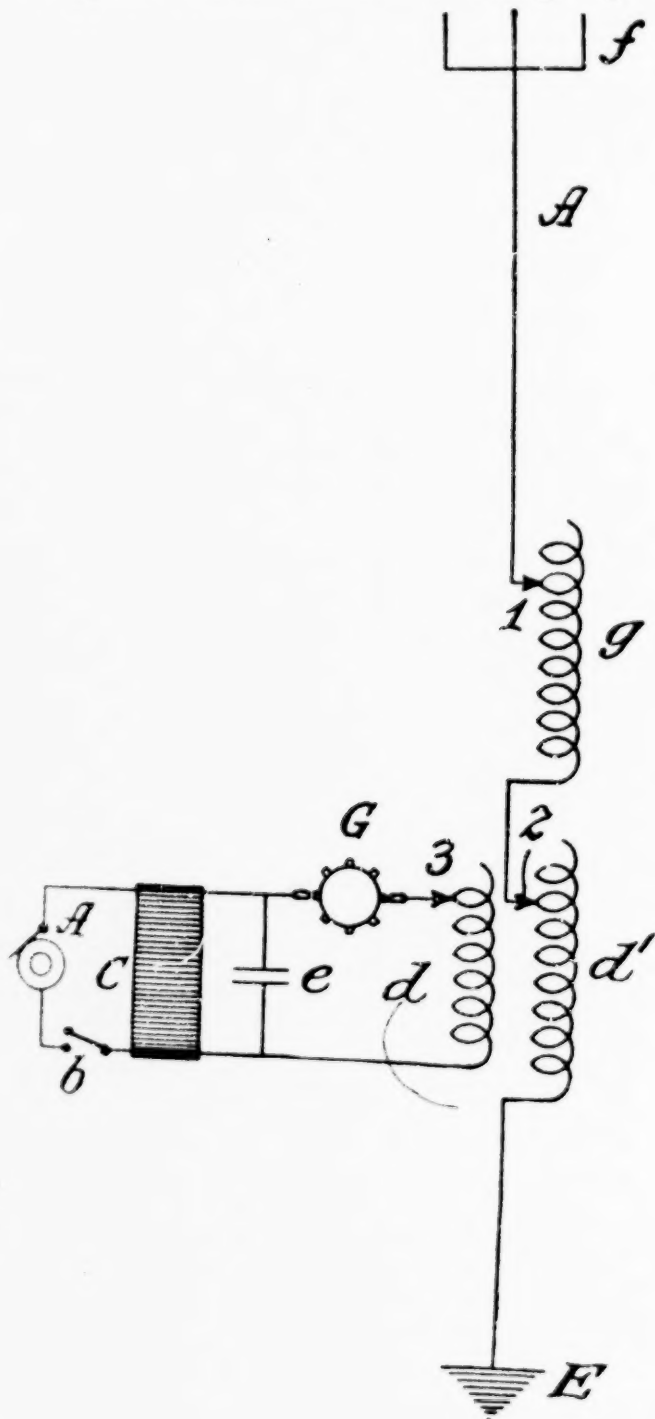
Typical Transmitter with Rotating Gap

Plaintiff's Exhibit 112

Typical Transmitter with Rotating Gap

2789

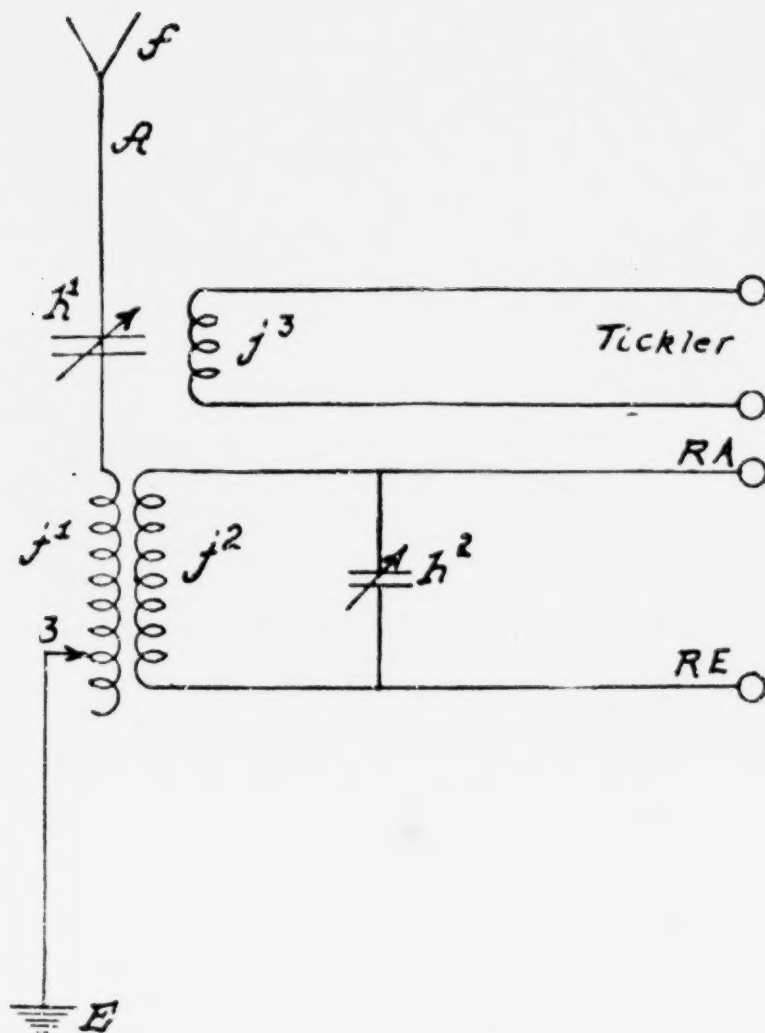
2790



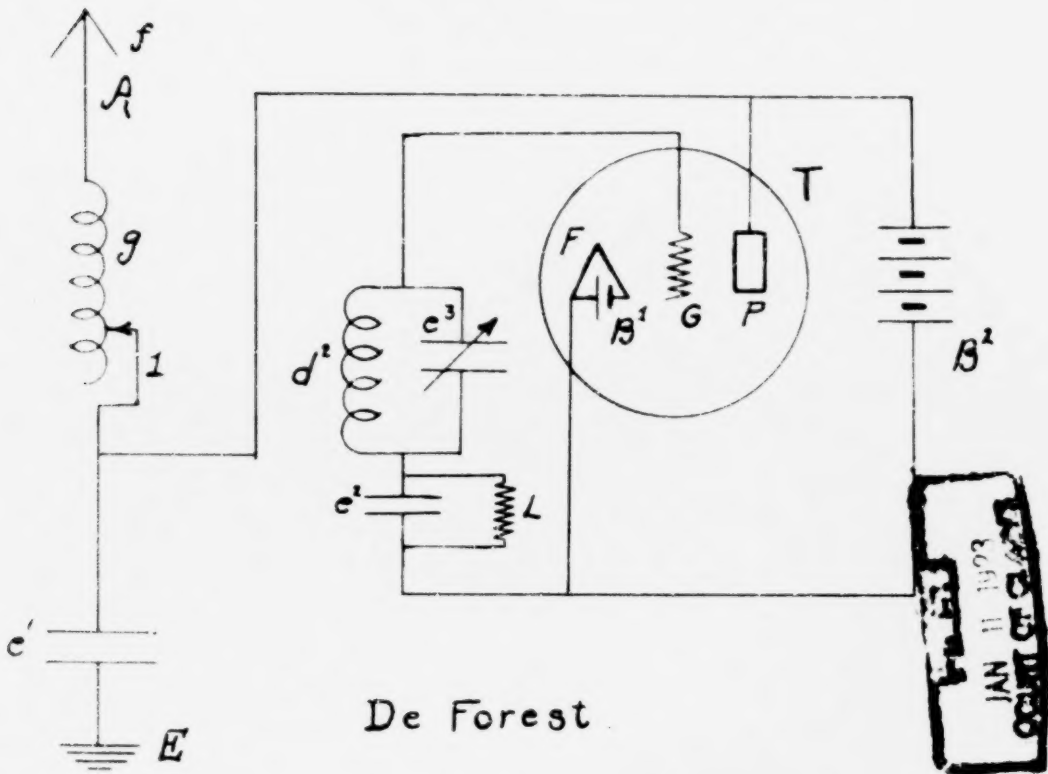
2423

Plaintiff's Exhibit 113

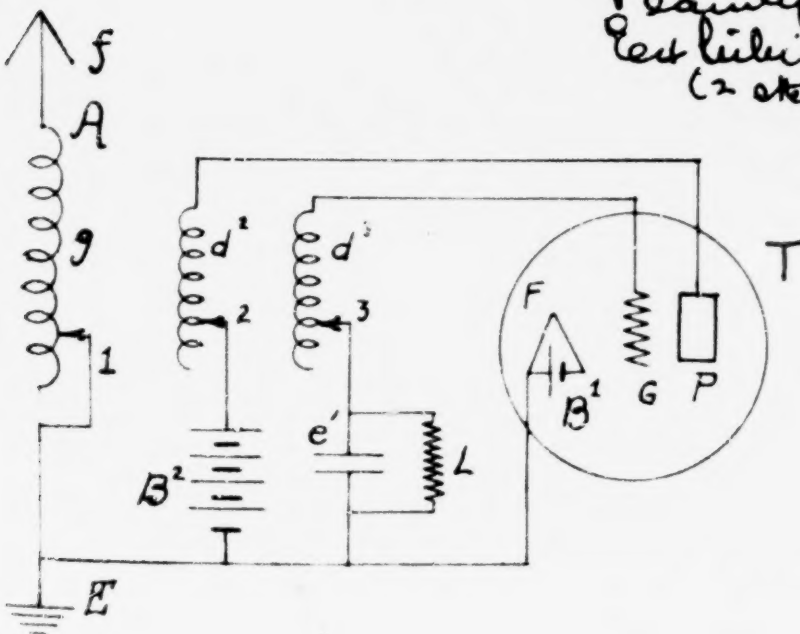
*Receiver arranged with  
terminals for any form of detector*





PLAINTIFF'S EXHIBIT 116*Vacuum Tube Transmitters  
for Radio Telephony*

*Marconi vs.  
See U.S. # 33642  
Plaintiff's  
Exhibit 116  
(2 sketches.)*



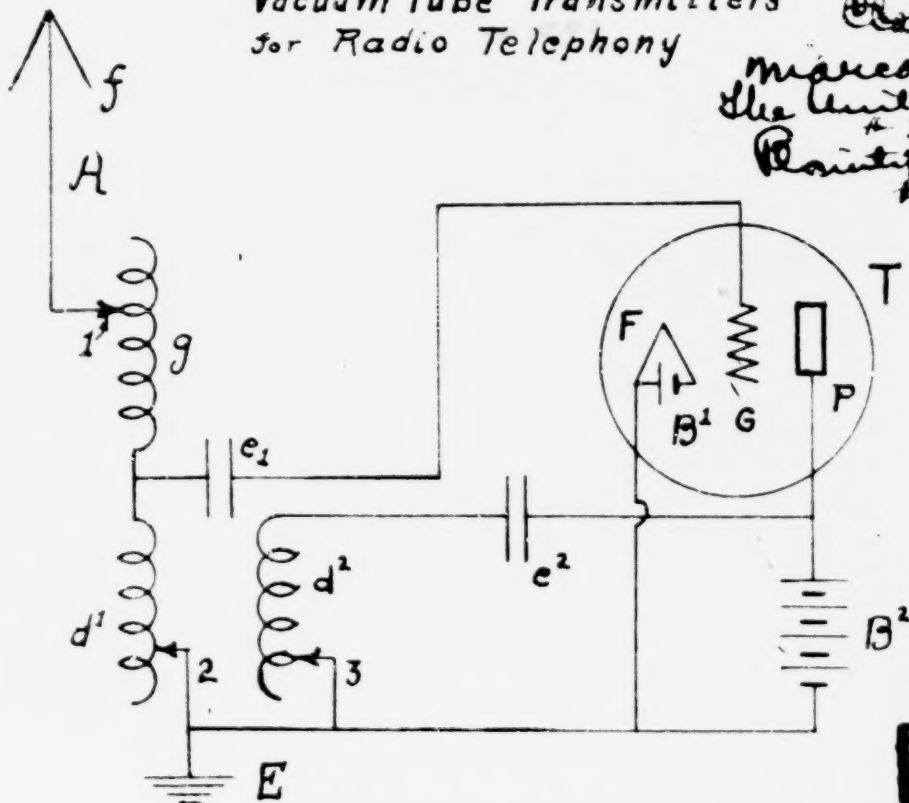
General Electric (No 1)

2426

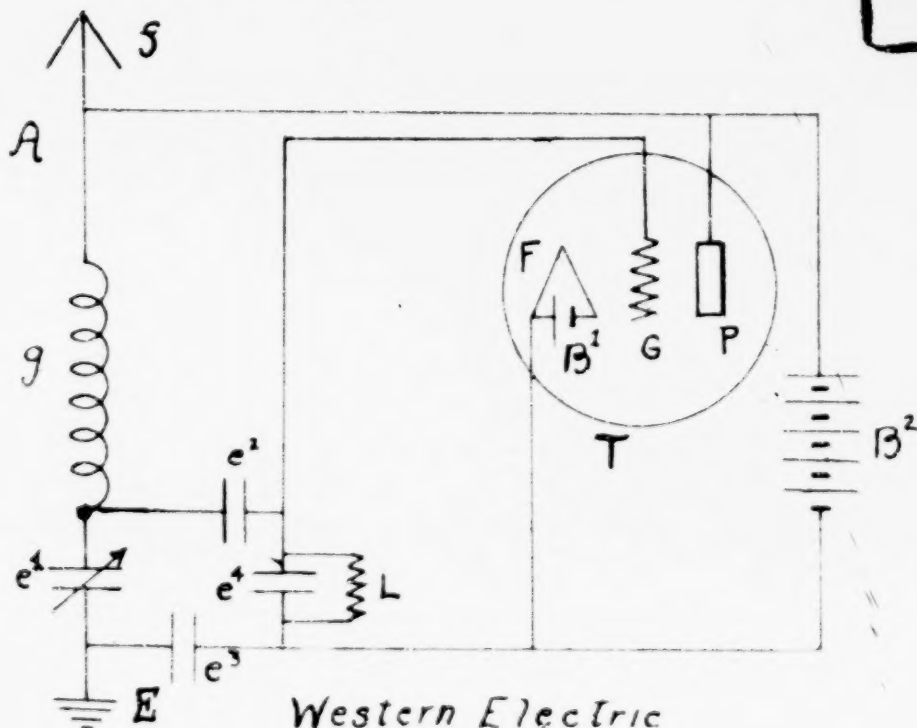
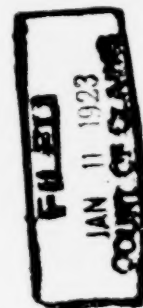
2426

Vacuum Tube Transmitters  
for Radio Telephony

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INTERFERENCE IN WIRELESS TELEGRAPHY

By JOHN STONE STONE

Read before the Electrical Section, 9th March, 1905

Introduction

Of the various problems which have been presented in the course of the development of the new art of wireless telegraphy, none is of greater interest to the engineer and none is of more far-reaching importance from the industrial and commercial standpoint than that of rendering the receiving instruments of wireless telegraph stations immune from interference.

There are two principal kinds of interference

1st. Interference which arises from electrical charges which accumulate upon the vertical oscillator under various conditions of weather, provided the vertical oscillator has no adequate electrical connection to the earth.

2nd. Interference which arises from such stray electromagnetic waves as are produced by lightning, by magnetic storms, by sparks in neighboring circuits, such for instance as occur in trolley circuits, and also from the electromagnetic waves emanating from wireless telegraph stations other than that with which communication is desired.

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### INTERFERENCE DUE TO STATIC CHARGES.

The interference which results from the first of these two sources is readily overcome since the oscillator of a wireless receiving station may always be given a metallic connection to the earth sufficient to maintain it clear of statical charges without in any appreciable degree interfering with its operation as a receiving oscillator.

Thus for instance if the vertical oscillator includes a condenser insulating a portion of the vertical oscillator from the earth, the condenser may be shunted by a coil of inductance so large that

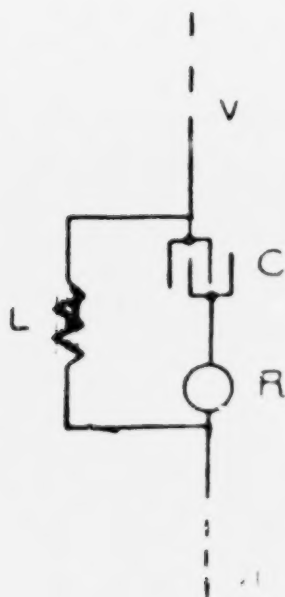


Fig.

for the high frequencies employed in wireless telegraphy it will operate practically as an open circuit, whilst affording a ready path to earth for the electrical charges which, in its absence, would accumulate upon the vertical oscillator and produce disruptive discharges to earth.

Again, if a highly sensitive detector or receiving device be included directly in the vertical receiving oscillator, such an inductance coil may be placed in shunt to the receiver without appreciably affecting its sensitiveness. The coil will then serve as a by-path for the currents due to the passage of the charges of the vertical oscillator to the earth.

Another device which may serve to still further protect the receiver under these conditions is that illustrated in Fig. 1, in which

$V$  and  $V_1$  are portions of the vertical oscillator system,  $L$  is a coil of large inductance,  $R$  is the receiving device, and  $C$  is a condenser of capacity so large as not to impede appreciably the passage of the high-frequency oscillations of wireless telegraphy while acting practically as an open circuit for the more slowly varying currents by which the vertical oscillator is maintained free of static charges.

The greatest security from this form of interference is however obtained by providing the vertical receiving oscillator with an adequate conductive connection to earth and by placing the receiving device in a local circuit made resonant by a coil and a condenser to the frequency of the electrical oscillations to which the receiver is intended to respond.

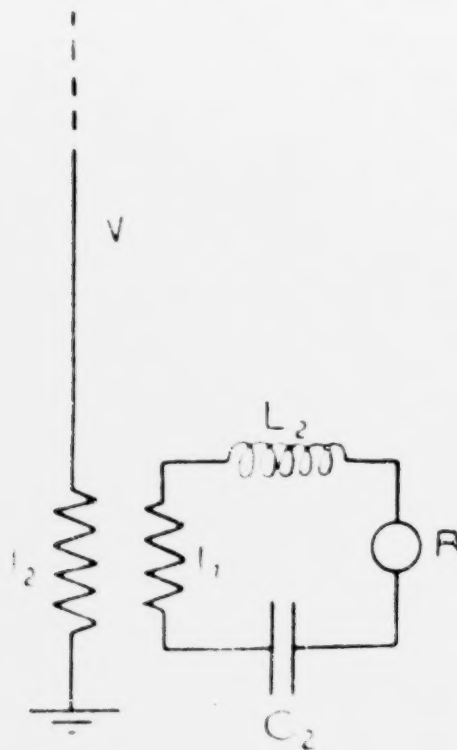


FIG. 2

An example of such an arrangement is shown in Fig. 2, in which  $V$  and  $V_1$  are the vertical receiving oscillator,  $I_1$  and  $I_2$  are the windings of a high frequency transformer,  $R$  is the receiver,  $C_2$  is a condenser and  $L_2$  is an inductance coil.

The manner in which the local circuit containing the receiver is made resonant to the frequency of the oscillations to which it is intended to respond will be considered later in this paper. It is

sufficient here to note that the local circuit being resonant to a frequency sufficiently high for the purposes of wireless telegraphy, will not be appreciably affected by the more slowly varying currents in the vertical oscillator by which the latter is maintained free from static charges.

#### INTERFERENCE DUE TO ELECTROMAGNETIC WAVES.

Coming now to the prevention of interference by electromagnetic waves such as emanate from other wireless stations than that with which it is desired to hold communication, and to the prevention of interference by stray electromagnetic waves, we find that the solution of the problem depends upon the character of the message-bearing wave, the energy of which it is desired to convey to the receiving device, and also upon the character of the disturbing waves, the energy of which it is desired to exclude or divert from the receiving device.

We can control the character of the waves whose energy we wish to receive, by suitably designing the apparatus to be used at the transmitting station, but we have no control over the character of the disturbing waves except in so far as these arise from wireless stations within operative range of the receiving station.

The simplest solution of this problem is to cause each transmitter to send out its signals by means of *persistent trains of simple harmonic waves* of a frequency materially different from that employed by any other transmitter within operative range of the receiving station with which communication is to be maintained and to make each receiver responsive only to *persistent trains of simple harmonic waves* of the frequency employed by the transmitter with which it is in communication.

By this means the system is rendered selective and becomes a multiple system of telegraphy, permitting the operator at each station to select the station with which he wishes to hold communication to the exclusion of all the other stations, and by which a number of messages may be transmitted simultaneously in a given region without interfering with one another.

Since the stray electromagnetic waves arising from lightning etc., are not persistent trains of simple harmonic waves, but partake more of the character of isolated impulses, the receiver in such a system does not respond to such stray electromagnetic waves and it is therefore also freed from interference which would otherwise arise from such sources.

The manner in which a transmitting station is made to develop persistent trains of simple harmonic electromagnetic waves

of one frequency to the exclusion of waves of other frequencies, though simple in itself, in practice requires the strictest attention to certain details, and these may be best understood by the consideration of a concrete case, this being the manner in which such problems are usually presented to the engineer if not to the inventor.

#### Transmitter.

In modern wireless telegraphy the messages are transmitted by electromagnetic waves which are horizontally polarized at the earth's surface, and which are developed by electrical oscillations set up in an electrical oscillator whose axis is normal to the surface of the earth and which is connected to the earth at its lower extremity.

The reason for employing waves of this type and so developed, is that such waves have, at the earth's surface, no component of electric force parallel to the surface and no component of the magnetic force normal to or cutting that surface, except in the immediate neighborhood of the base of the transmitting oscillator. As a result they do not tend to induce currents in the surface of the earth as they travel away from the transmitter except where the surface of the earth deviates from the plane of polarization of the waves at that surface. The energy which would otherwise be rapidly dissipated through the production of induced currents in the earth is therefore conserved in the waves. Moreover when a deviation occurs between the plane of the earth's surface and the plane of polarization of the waves at the earth's surface, the currents induced in the surface of the earth are such as to bend the wave front into a position normal to the surface with the result that the waves travel over and around mountains and in fact follow the earth's surface whatever be its contour, instead of tending to travel in straight lines like ordinary light waves and as would be the case with vertically polarized electromagnetic waves.

For a more complete exposition of these points see a paper read by the Author at the International Electrical Congress held at St. Louis, Sept. 12 to 17, 1904, and reprinted in the Electrical Review, New York, Oct. 15, 1904.

There is not space in this paper to discuss in detail the development of the waves described above, but their genesis and mode of propagation is clearly suggested by Figs. 3 to 8. Fig. 3 and Fig. 4 illustrate the development of a wave by free electrical oscillations in a straight wire  $AOB$ , the curve lines indicating a line of electric force in its various phases from  $t=0$  to  $t=\frac{1}{2}T$ , where  $T$  is the time of a complete free electrical oscillation in the

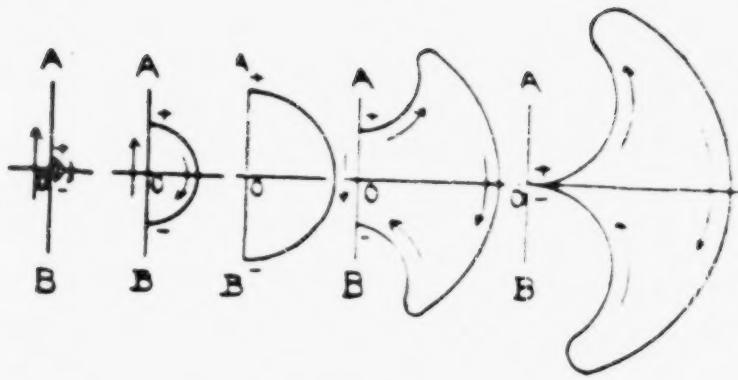


Fig. 3

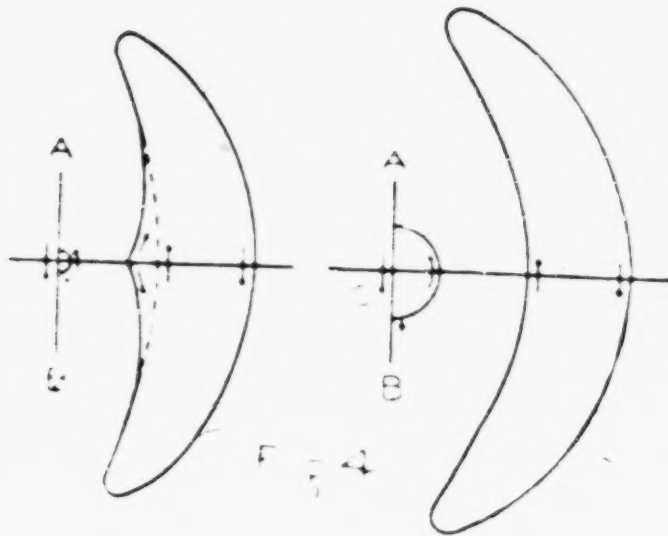


Fig. 4



Fig. 5



Fig. 6

wire. In Figs. 5 and 6 the genesis of a wave from a vertical linear oscillator  $A_0$  earthed at its lower extremity is illustrated, and in Figs. 7 and 8 the effect of an elevation and depression in the surface of the earth upon the wave fronts at that surface is indicated.

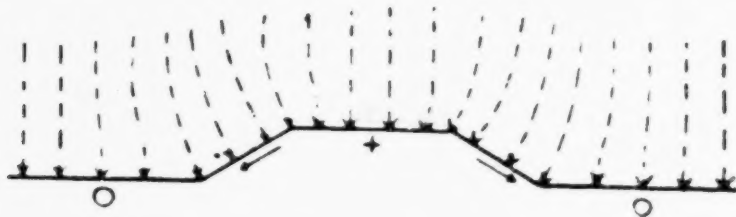


Fig 7

We may next consider the earth connection of the transmitting oscillator and the nature of the support for the oscillator.

Although, by the use of such waves as are described above, normally the current density in the surface of the earth at a distance from the transmitting oscillator is rendered excessively small, nevertheless at, and in the immediate neighborhood, of the base of the vertical oscillator, the current density is in general very great. Moreover since the current is of high frequency, it tends to flow only on the surface of the earth. For this reason the usual

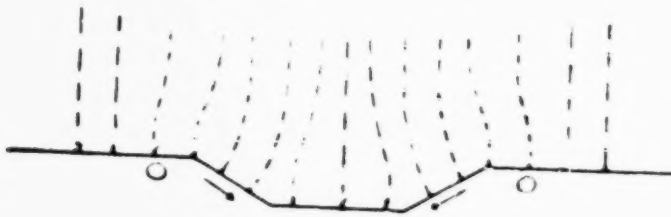


Fig 8

specifications for obtaining a good earth connection, which involves burying a conductor of large area so deep in the ground that it shall be in permanently moist earth, are no longer advantageous, and in a properly constructed wireless telegraph station the conductivity of the *surface of the earth* in the immediate neighborhood of the base of the oscillator is artificially increased by a *superficial ground-plate* composed of sheet metal, or of wire netting, extending radially from the base of the oscillator and covering as large an area about the base of the oscillator as is available for the purpose and consistent with reasonable economy.

Since the waves are horizontally polarized, the supports for the vertical oscillator, such as masts and guy-ropes, should either be of insulating material, or if of metal, they should be divided by insulation into sections short compared to one-half the wave-length of any of the waves to be employed. The reason for this is that the fundamental free period of vibration of a linear conductor is such as to cause it to respond most energetically to waves of twice its own length. For such wave-lengths, therefore, the linear conductor would absorb an undue amount of the energy of the waves and moreover because of the rise of potential which occurs at the ends of the conductor for waves of such length it would be difficult to insulate the conductor from the earth or adjacent portions of the support of the vertical oscillator.

We come now to the vertical oscillator itself. This in general consists of two parts, the elevated conductor *per se* and the devices through which it is connected with the earth.

We shall here consider the relatively simple case in which the elevated conductor is a straight, cylindrical copper wire of length  $a$  and radius  $\rho$ .

Both theory and practice show that the electrical vibrations in such a wire connected directly to the earth at its lower extremity correspond very closely to the transverse vibrations of a heavily damped stretched string.

If such a wire be charged to a high potential and be then permitted to discharge to earth, the electrical oscillations developed in it, and therefore also the electromagnetic waves radiated by it will not be simple harmonic in type and will not be persistent. These waves will not therefore correspond to the sound waves given out by a tuning-fork, but will be of the character of those given out by a heavily damped violin string plucked at its centre.

The fundamental of the waves given out by such an oscillator has a wave-length which very closely approximates four times the length of the wire, and this is accompanied by all the odd harmonics. The oscillations are so much damped by the energy drawn off from the oscillator by radiation as to make the resulting waves more nearly the equivalent of an impulse than of a sustained or persistent train of waves.

If, however, the elevated conductor be not directly connected to the earth, but be connected to it through an inductance coil, both theory and practice show that its electrical vibrations correspond to the transverse vibrations of a heavily damped stretched string with a mass attached to its centre.

The effect of the load at the centre of the stretched string and of the inductance at the base of the vertical wire is to increase the

persistence of the vibrations, to minimize the importance of the harmonics and to lower the frequency of the fundamental. It might therefore seem that in order to cause the vertical oscillator in question to radiate a persistent train of simple harmonic waves of a predetermined frequency, it would be sufficient to charge the

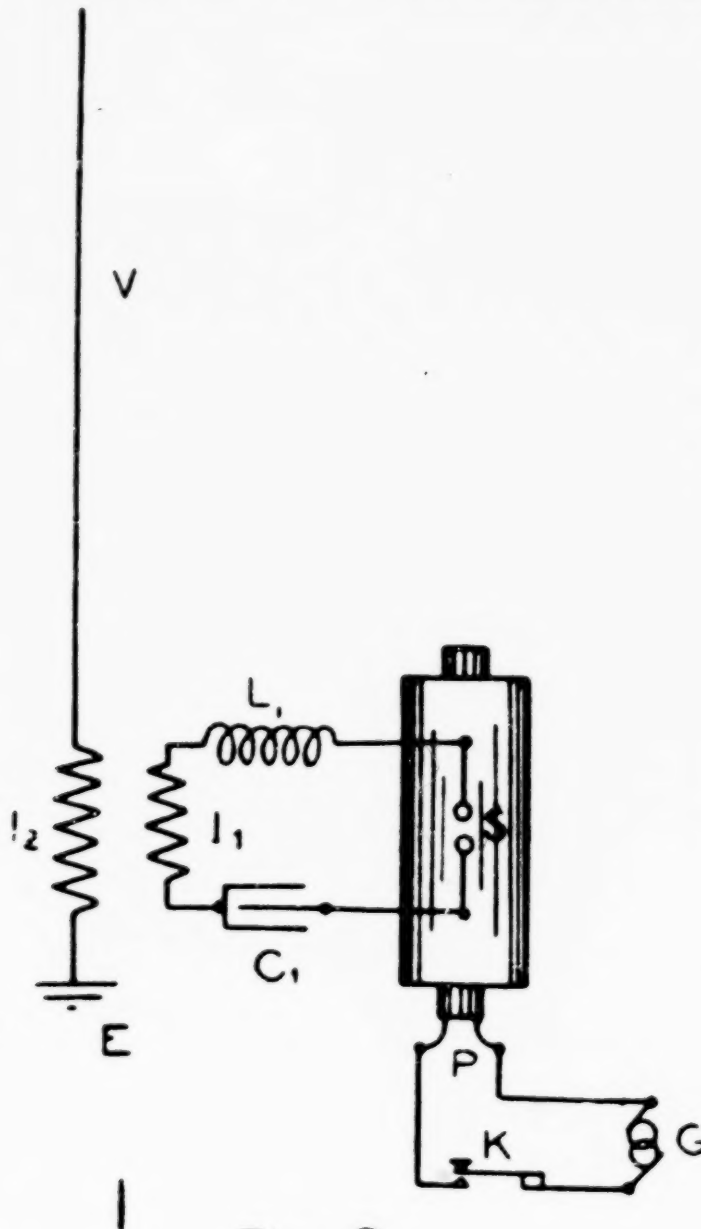


Fig 9

vertical wire to a high potential and permit it to discharge to earth through an inductance coil of suitable dimensions.

This indeed was the plan adopted in the first crude attempts at producing a selective system of wireless telegraphy. This method necessitates the use of waves of much lower frequency than that normally produced by natural vibrations in the vertical wire per se.

The degree of persistency of oscillations so obtained however, is not as great as is required in practice. Such persistency as is obtained is gained at the expense of the amplitude of the current oscillations in the vertical and at the expense of the radiating power of the oscillator, the latter being *ceteris paribus* less for low than for high frequencies. Moreover the spark in the vertical oscillator which normally dissipates an undue amount of the energy of the oscillations, has its resistance enhanced by the reduction of the amplitude of the current oscillations due to the presence of the inductance coil.

This latter difficulty may in a measure be overcome at the expense of any increase of the energy supplied to the oscillator, by shunting the spark gap by a condenser of large capacity. The discharge of the condenser across the spark gap increases the current through the spark and thereby reduces its resistance and damping effect upon the oscillations. The damping effect of the radiation still remains and the persistency is still too much diminished for practical purposes.

So far we have considered only the *natural oscillations* of the vertical oscillator which are produced by charging the elevated conductor to a high potential and then permitting it to discharge to earth. When, however, a high degree of persistency, a pure sine wave and a great amplitude of oscillation are desired, the spark gap is removed from the vertical oscillating circuit and a simple harmonic electromotive force is impressed upon the vertical oscillator in its place. The resulting vibrations in the vertical oscillator are then *forced simple harmonic vibrations*. In order that they may be of great amplitude, the frequency of the impressed force is made to correspond to the fundamental of the vertical oscillator or to one of its harmonics, in which cases the reactance of the vertical oscillator is nil.

A simple arrangement for producing forced, simple harmonic vibrations in the vertical oscillator is shown in Fig. 9 in which G is an alternating current generator, K is a key, P shows the connection to the terminals of the primary of a spark coil, S is a spark gap between the terminals of the secondary of the spark coil, C is a condenser, L is an inductance, I<sub>1</sub> and I<sub>2</sub> are the primary and secondary coils of a high-frequency transformer, V is the vertical wire and E is the earth.

There is a variety of ways in which substantially the same result may be accomplished, but there is not space in this paper to consider more than one arrangement.

The type of elevated conductor which we are here considering is a cylindrical copper wire of length  $l$  and radius  $a$  the reactance

of the elevated conductor *per se* is given with a degree of approximation ample for engineering calculations by the expression;—

$$Z = -Lv \cot \frac{n\lambda}{v}$$

where  $L = 2 \log_e \frac{4a}{\rho} - k$

and where  $k = 5.584 - 3.169 \left( \frac{n\lambda}{v} \right)^2 - 0.3269 \left( \frac{n\lambda}{v} \right)^4$  for values of  $a$  between 0 and  $\frac{v}{2n}$

In these expressions  $v$  is the velocity of light and  $n$  is the periodicity of the impressed force or  $\frac{2\pi}{T}$  where  $T$  is the time of a complete oscillation.

The reactance  $Z$  therefore vanishes when  $n = \frac{m}{4a} v$  where  $m$  is an odd integer. The wave lengths corresponding to this condition are therefore  $\lambda = vT = \frac{4a}{m}$ . The wave-length of the fundamental is therefore  $4a$  and the harmonics are all odd.

For frequencies lower than the fundamental the reactance is negative or a capacity reactance. For frequencies between that of the fundamental and its first harmonic the reactance is positive or an inductance reactance. For frequencies between that of the first even harmonic and the first odd harmonic the reactance is again negative or a capacity reactance. In other words, the reactance of the vertical wire measured at the source or driving point of the system is either that of a condenser of capacity  $C = \frac{1}{4\pi a} \cot \frac{n\lambda}{v}$  or of an inductance  $L = \frac{1}{4\pi a} \tan \frac{n\lambda}{v}$  depending upon whether  $\cot \frac{n\lambda}{v}$  is positive or negative.

The condition for zero reactance in the vertical oscillation system is obviously  $Z_1 + Z_2 = 0$  where  $Z_2$  is the reactance of the apparatus connected between the vertical wire and the earth. It must therefore be an inductance reactance for frequencies which make the reactance of the vertical wire a capacity reactance.

(1) The values of  $k$  have been here calculated from the formulae given by Lord Kelvin in his paper on the "Theory of the Capacity of a System of Two Conductors," the formula being based upon the assumption that the conductors are infinitely long. The values of  $k$  for finite conductors are given in the paper by Lord Kelvin.

conversely it must be a capacity reactance for frequencies which make the reactance of the vertical wire an inductance reactance.

The curve shown in Fig. 10 gives the observed apparent capacity of vertical wires 0.708 in diameter varying from 40 to 180 feet in length, when the periodicity of the impressed force is  $9.78 \times 10^{-8}$ . In other words it gives the observed apparent capacity of vertical wires for values the angle of  $\frac{10^8}{v}$  from 0.3376 to 1.790 and for values of the ratio  $\frac{4\pi}{\lambda}$  from 47,520 to 213,800.

The reactance  $Z_0$  of the apparatus through which the vertical wire is connected to ground may most simply be made negative, when this is necessary, by the insertion of a condenser in series with the coil  $L_1$ , but this result may be accomplished in a variety of ways for the description of which there is not space in this paper.

It will be seen that by making  $Z = Z_0$  or  $Z$  equal, but opposite in sign to the reactance of the elevated conductor, powerful oscillations of any desired frequency may be developed in the vertical oscillator by means of forced vibrations, whereas when the natural oscillations of the vertical oscillator are resorted to the frequency must necessarily be less than that of the fundamental of the oscillator.

Concerning the arrangement illustrated in Fig. 9, there is much of detail which requires attention in order that the apparatus shall satisfactorily fulfil the requirements of radiating a persistent train of simple harmonic waves. For instance, if a dielectric having considerable electrostatic hysteresis be employed in the condenser, a surprisingly large amount of energy will be dissipated in this dielectric. The magnitude of this loss is due to the fact that the energy dissipated increases both with the potential difference employed at the terminals of the condenser and also with the frequency. Since potential differences developed at the terminals of the condenser amounting to 50,000 volts and oscillations having frequencies of 5,000,000, are not unusual in wireless telegraphy, it is easy to see that the losses in the dielectric of a condenser in a wireless telegraph circuit are of a far greater order than that in the dielectric of condensers employed in the usual power or lighting circuits.

Moreover the specific inductive capacity of most dielectrics is a function of the density of the displacement current in the dielectric, and when such dielectrics are employed in the condenser in an oscillating circuit the resulting oscillations are not simple harmonic in form and are not isochronous throughout the train, in series with the coil  $L_2$ , but this result may be accomplished in

Air condensers should therefore be used in wireless telegraphy to the exclusion of any other type pending the publication of the results of certain investigations which are being conducted with the view of supplying a dielectric of high dielectric strength and constant specific inductive capacity.

The coils used in wireless telegraphy should not have iron cores except the iron be very finely comminuted and imbedded in a non-hygroscopic dielectric matrix. It has even been found by the author that coils wound on a wooden cylinder do not operate satisfactorily when used in the oscillating circuits of wireless telegraphy. The coils for this purpose are best constructed by winding a few turns of bare copper wire in a single layer on a skeleton frame made of ebonite, care being taken to separate the turns by such an amount that the sum of the air spaces between the wires of the turns is equal to or slightly greater than the sparking distance in air corresponding to the greatest potential difference liable to occur at the terminals of the coil when the apparatus is in operation.

If the local oscillating circuit  $C_1$ ,  $I_1$ ,  $L_1$ ,  $S$  of the arrangement shown in Fig. 9 were isolated, its oscillations would be expressed

$$\text{by } i = \frac{e}{L} \frac{1}{\sqrt{1 - \frac{R^2}{LS - 4L^2}}} e^{-\frac{R}{2L}t} \sin \sqrt{\frac{1}{LS - \frac{R^2}{4L^2}}} t \quad \text{where } i$$

is the current,  $e$  is the potential to which the condenser  $C_1$  is charged at the time when the spark occurs at  $S$ ,  $L$  is the inductance of the circuit,  $R$  is the resistance and  $S$  is the permittance or electrostatic capacity of the condenser.

If the oscillator is at all persistent  $\frac{R^2}{4L^2}$  is negligible compared to  $\frac{1}{LS}$ , and the expression reduces to

$$i = e \sqrt{\frac{S}{L}} e^{-\frac{R}{2L}t} \sin \sqrt{\frac{t}{LS}}$$

The time required to fall to  $\frac{1}{e}$ th of their initial amplitude is therefore  $t = \frac{2L}{R}$

The number of oscillations per unit of time is  $\frac{1}{2\pi \sqrt{LS}}$

The measure of the persistency of the circuit is therefore proportional to  $\sqrt{\frac{L}{R^2S}}$

For a given frequency,  $L_n = \frac{1}{Sn}$  so that the persistency for a given frequency is proportional to  $\frac{L_n}{R}$ , where  $n$  is 2 $\pi$  times the frequency.

An isolated circuit of this type may be made to give extremely persistent simple harmonic oscillations, but if it be given a large co-efficient of mutual induction with another oscillator of relatively low persistency, such as the vertical oscillator  $VI_2E$  of the arrangement shown in Fig. 9, two things happen. In the first place the oscillations of the circuit are in general no longer simple harmonic, but are broken up into two simple harmonic oscillations of different frequencies, and in the second place the persistency is greatly reduced.

To overcome this difficulty it is necessary either to make the magnetic leakage of the high frequency transformer, connecting the local oscillating circuit with the vertical oscillator, unusually large, or else to add to the local oscillating circuit an inductance coil  $L_1$  with sufficient inductance to swamp by its effect the reaction from the secondary circuit.

When intense radiation is desired, it is necessary to make the capacity  $S$  of the condenser  $C_1$  in the local oscillating circuit large compared to  $S'$  the apparent capacity of the elevated conductor *per se*, for the frequency employed.

#### Receiver.

Since the electromagnetic waves to be received at a wireless telegraph receiving station are horizontally polarized at the earth's surface, an electrical oscillator whose axis is normal to the earth's surface is employed at the receiving station. This oscillator may either be connected to earth at its lower extremity or it may be connected to a device having reactance equal for all frequencies to the reactance of the vertical oscillator. It is to be remembered in this regard that at the receiving station we are not concerned with what becomes of the energy which is dissipated by the re-radiation of the energy from the receiving vertical oscillator.

We shall consider again a simple concrete case, and shall assume the elevated conductor to be a cylindrical copper wire of length  $a$  and radius  $b$ , as in the case of the transmitter, though it must by no means be assumed that the elevated conductor at the receiving station must necessarily be similar to that at the

transmitting station, or, in fact, that it must bear any resemblance to that at the transmitting station except in so far as its axis is preferably normal to the surface of the earth.

As in the case of the transmitting station, only one simple arrangement of the apparatus sufficient to give the desired result will here be considered. By this arrangement messages transmitted by means of persistent trains of simple harmonic electromagnetic waves of a predetermined frequency may be received to

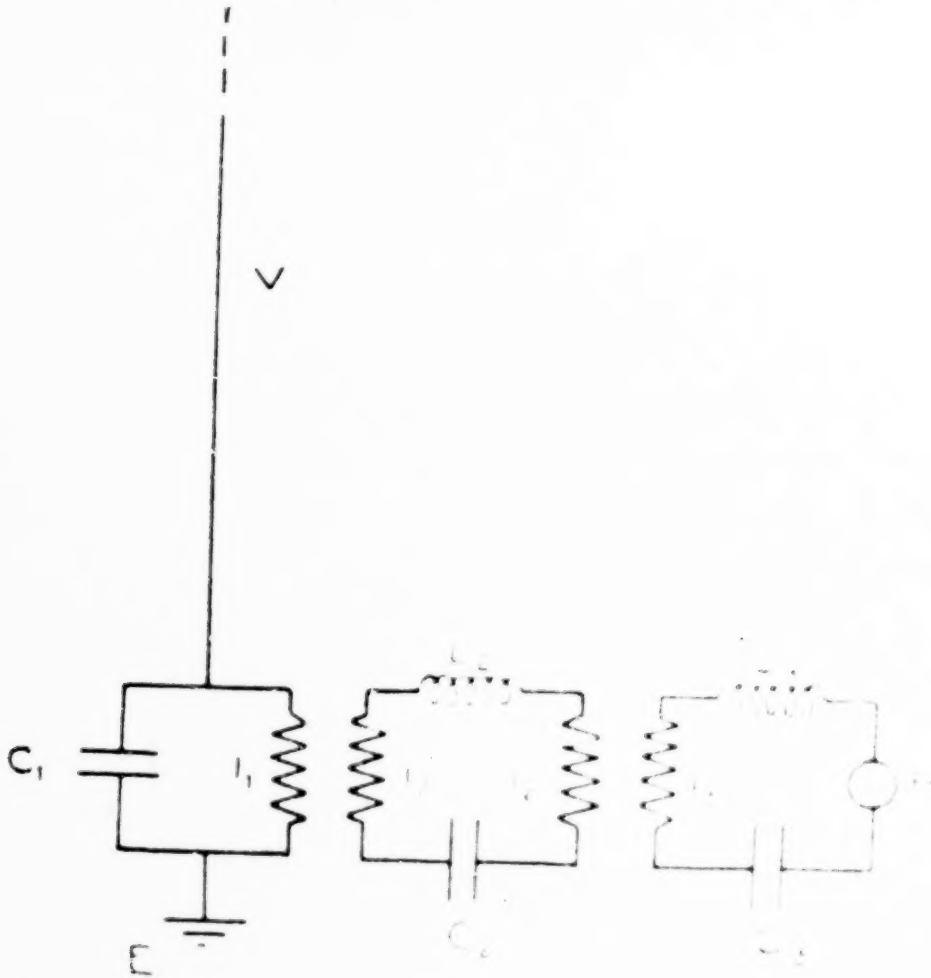


FIG. 1.

the exclusion of messages transmitted by similar waves of totally different frequencies, and without interference by other waves. Such an arrangement of the circuits and apparatus is shown in the diagram 11. In this arrangement the device which is indicated at R is placed in a series with  $L_1$  &  $R$  which is made resonant to the frequency of the waves which the station is intended to respond to and to reject all

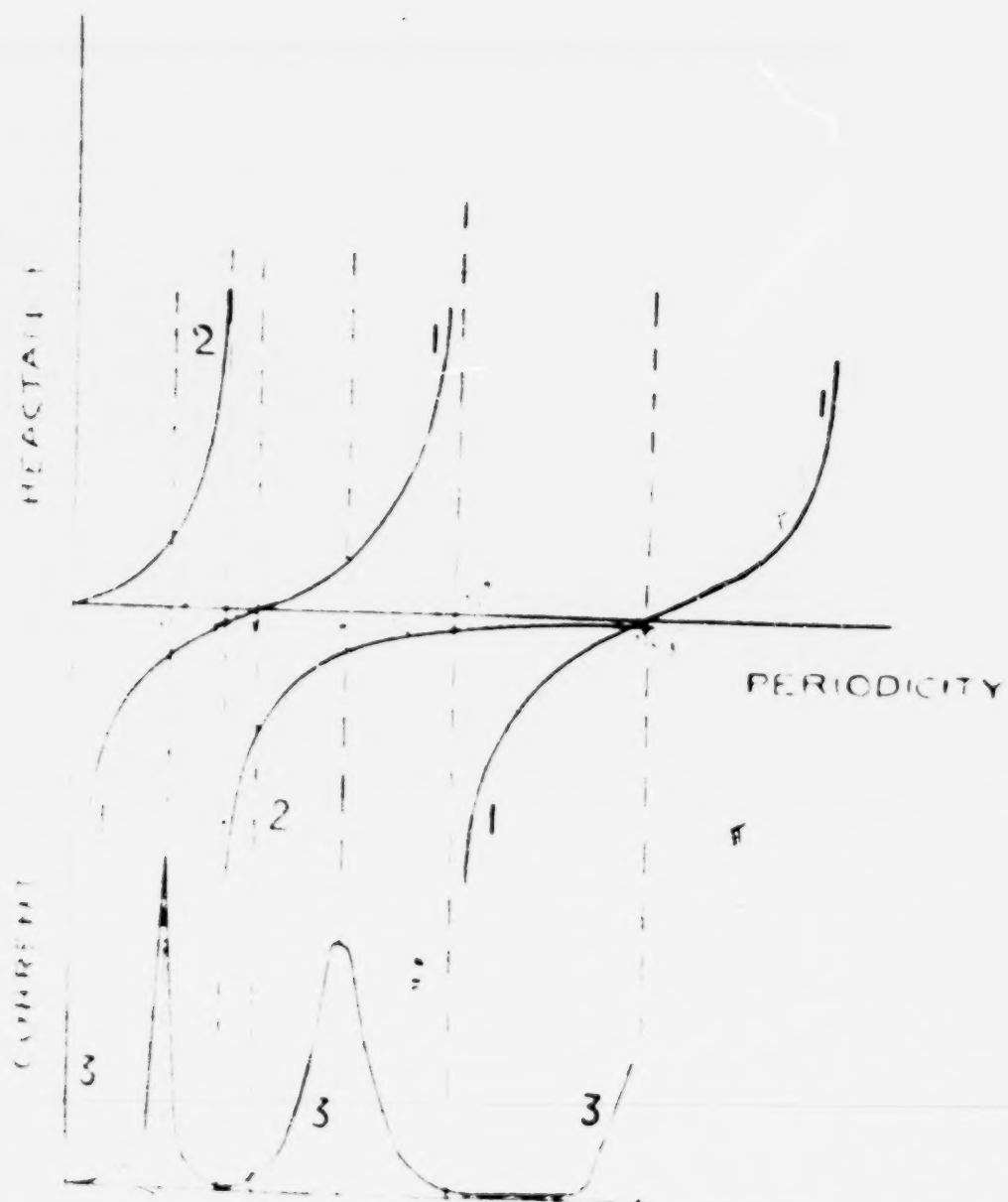


FIG 12

circuit  $C, I, L, I_2$  resonant to the same frequency and called a "weeding-out circuit", is interposed between the first mentioned circuit and the vertical oscillator.

The branch circuit consisting of the coil  $I_2$  and condenser  $C$  is not, when taken by itself, resonant to the same frequency as the other local circuits, but is so proportioned that when connected as a branch circuit, forming a part of the vertical oscillator system, the latter shall respond most energetically to persistent trains of waves of that frequency falling upon the vertical wire.

The way in which this is accomplished is perhaps more easily seen by a graphical demonstration than by the use of the analytical solution, though the latter is by no means difficult.

The curves in Fig. 1 illustrate the point in question. Curve 1 represents the reactance of the vertical wire measured at its point of attachment to the loop circuit, for varying periodicities of the impressed force. It will be seen that the periodicity of the fundamental of the vertical wire is at the point  $n_1''$ , where the reactance first vanishes. The first even harmonic is at  $n_2''$ , and the periodicity of its first odd harmonic is at  $n_3''$ , where the reactance again vanishes. Normally therefore curve 3, which is the current curve for varying periodicities of the impressed force on the vertical wire would show maxima at  $n_1''$  and at  $n_3''$ . The reactance of the loop circuit for varying periodicities of the impressed force, measured across the points of its attachment to the vertical wire and earth connection is shown in Curve 2. The total reactance of the vertical oscillator measured at the earthed terminal is the algebraic sum of the two reactances shown in Curves 1 and 2, and as a result the current curve 3 shows maxima, not at  $n_1''$  and  $n_3''$ , but at periodicities  $n, n''$  and at a periodicity slightly higher than  $n_1''$ .

These are the points at which the reactance of the loop circuit is equal, but opposite in sign, to that of the vertical wire.

The periodicity of the local loop circuit *per se* is  $n_1'$  and for this periodicity the current in the vertical wire is practically nil.

The "weeding-out circuit" and the circuit containing the receiver are both resonant to the periodicity  $n$ , so that for persistent trains of waves of that periodicity the energy of the oscillations set up in the vertical oscillator is transmitted directly to the receiver, but persistent trains of waves of other frequencies, either produced by slight response in the vertical oscillator or else produced oscillations of the periodicity  $n''$ , or of a periodicity slightly higher than  $n_1''$  have little effect on the receiver. To such periodicities the "weeding-out circuit" and the circuit containing the receiver are extremely irresponsive so that the receiver

ing device receives but an inappreciable amount of the energy of the waves.

In the case of impulsive waves the vertical wire tends to respond only to its own natural rates of vibration as affected by the loop circuit, that is to say, it tends to oscillate at periodicity  $n''$  and to upper harmonics. Such waves acting on the vertical wire, have little tendency to develop oscillations of the natural period of the loop circuit as affected by its connection with the vertical wire, namely  $n$ , and the receiver is therefore also protected from the effects of such impulsive waves.

All that has been said regarding the effects of electrostatic and magnetic hysteresis in the description of the transmitting station applies with added force to the apparatus at the receiving station. It is, in fact, much more important to exclude the effects of hysteresis from the receiving circuits than from the transmitting circuits, and it may be laid down as an important rule that under no circumstances shall solid or liquid dielectrics be used in the receiving circuits.

Moreover the injunction in regard to making the mutual inductance small between oscillators at the transmitting station applies in the case of the resonant circuits at the receiving station, since if the mutual energies of the related resonant circuits be not small compared to their self energies, the resonant circuits will modify one another's natural periods and each circuit will respond to more than one periodicity.

Finally it may be said the measure of the selectivity of a resonant circuit is proportional to  $\sqrt{\frac{L}{R^2S}}$ , this expression being the same as that found in connection with the persistency of an oscillating circuit. For a given periodicity, therefore, the selectivity is proportional to  $\frac{L_0}{R}$ .

So great is the selectivity of resonant circuits constructed of air condensers and properly designed inductance coils that there is no difficulty in adjusting such circuits to resonance for a given frequency with an error of less than one part in 3,000.

The importance of the "weeding-out circuit" in the receiving station becomes apparent when we observe that the selectivity of the receiving vertical oscillator is greatly diminished by the dissipation of energy, which results from the re-radiation of energy by that oscillator and that the selectivity of the resonant circuit containing the receiver may be greatly diminished by the energy absorbed by the receiver and utilized in its operation.

{fol. 2446] PLAINTIFF'S EXHIBIT No. 120

IN THE COURT OF CLAIMS OF THE UNITED STATES

MARCONI WIRELESS TELEGRAPH COMPANY, Plaintiff,

vs.

UNITED STATES, Defendant

Copy of Preliminary Report of Interdepartmental Radio Board on Plaintiff's Claim and Accompanying Letter of Oct. 8, 1920. Luella F. Little, Notary Public

INTERDEPARTMENTAL RADIO BOARD,  
3341-3343 New Navy Building,  
Washington, D. C.

October 8, 1920.

Gentlemen:

There is enclosed herewith draft of preliminary report as to your claim against the United States for compensation for use of your inventions in radio patents. The report is to be understood as involving no waiver or admission on the part of the Government in case a settlement is not reached between it and Claimant. In applying the views expressed in this preliminary report to a review of the radio apparatus purchased or manufactured by the Government, the Board considers that a fair compensation to be allowed in the matter of this claim is \$1,063,701.82.

Due steps are being taken to render effective the results arrived at by the Board and the payment of awards finally agreed upon. Meanwhile, an opportunity is offered the Claimant to review the Board's report with a view to reaching agreement between the Board and the Claimant. To this end the Board has set apart Monday the 18th of October, 1920, at 10 A. M., for further discussion of this claim with you and your counsel. Please advise the Board as to whether you will attend on that day. It is pointed out that it has been necessary to set other days of the two weeks beginning 18th October for hearing other claimants, so that it will be difficult to change the date assigned to you, and it

is important, in view of the approaching assembly of Congress, that the matter be disposed of at the time set.

Very respectfully, (signed) E. H. Loftin, Lieutenant-Commander, U. S. N., Chairman.

Marconi Wireless Telegraph Co., Woolworth Bldg., New York City. Copy to Messrs. Sheffield & Betts.

[fol. 2447]

# CLAIM No. 2

## Marconi Wireless Telegraph Co.

¶ This claimant is the owner of a large number of patents, a list of which is given in the papers presenting the claim, but pressed its claim only upon the following four patents with the understanding that if a settlement were reached thereon, all claim would be waived as to these other patents:

Re 11,913, Marconi, 609,154 Lodge, 763,772, Marconi, 803,684, Fleming.

Reissue 11,913, to Marconi, granted June 4, 1901, of original patent of Marconi No. 586,193, granted July 13, 1897, on application filed December 7, 1896

This patent expired July 13, 1914. It is the fundamental Marconi patent and has been thoroughly tested by litigation, the result being that while Mr. Marconi's invention was recognized as effecting a most important step in the art, the patent has not been given an effective place by the Courts corresponding to its apparent importance. In the original litigation before Judge Townsend, the first claim of the patent was held to be invalid and it was afterwards cancelled by this claimant. The third claim was held to be valid and to be infringed by the then DeForest structure which included as its detecting element an imperfect contact device operating on the opposite or inverse principle to the Marconi Coherer. The fifth claim involving the use of choke coils was also sustained and held infringed. The claims including the powdered form of the coherer and the provision of an automatic decoherer were held not infringed. The DeForest arrangement, as to the relation between the detector or the spark transmitter and the antenna seems to

have given Judge Townsend no difficulty in this case. (138 Fed. 657, *Marconi v. DeForest*.)

When the patent again came before Judge Townsend (*Marconi v. American DeForest*, 154 Fed. 74) on motion for preliminary injunction, the Court refused an injunction as to DeForest's new apparatus which included a loop radiator and receiver and an electrolytic detector.

When the patent was again tested in the suit before Judge Veeder against National Electric Signaling Co., claim 3 was the only one passed upon and was held to be not infringed on two counts; one, by reason of the removal of the spark producer at the transmitter and the detector at the receiver out of the antenna, and, two, by reason of the employment of a form of detector which was not, in the opinion of Judge Veeder, an imperfect contact such as contemplated by Marconi. Whatever may be the view of the Board as to the Processes whereby Mr. Marconi seems to have been deprived of a result equal to the real scope and value of his invention, the Board does not feel it can go beyond the opinion of Judge Veeder, which has not been modified by any later decision, and as there has been brought to the attention of the Board no instance of a use by the Government which would come in conflict with the [fol. 2448] scope of the claim as defined by Judge Veeder, no allowance can be made on the claim under this patent.

609,154, to Lodge, Granted August 16, 1898, on Application Filed February 1, 1898; Expired August 16, 1915

Reference is made to paper No. 11 in the appendix for the history of the litigation under this patent. Its validity has been uniformly sustained and it is accepted by the Board as the fundamental patent on the use of loading coils in the antenna whether at the transmitter or receiver. A part of the patent which has not been made the subject of claim for infringement but which has been discussed as to its bearing upon the Marconi "four circuit tuning" patent 763,772, is the structure illustrated in Figs 3 and 4 of the Lodge patent and referred to in claim 6. The system here involves, besides the means for synchronizing the radiating circuit, "means for charging it by an aerial disruption or impulsive rush." It is considered that this feature of the Lodge invention is in effect carried out in lesser degree than that specified by Lodge, but still effectively, in those Government stations in which a quenched gap excitation is em-

ployed. (See in this connection opinion of Judge Neterer in *Marconi v. Kilbourne & Clark*, 239 Fed. 328.)

The patent to Lodge, therefore, will be given, in accounting, a weight due both to the synchronizing coils and to the employment of impulse excitation in transmitters employing the quenched gap or other form of impulse excitation, if there be any.

*Laches.* From the time of grant of this patent, August 16, 1898, or shortly thereafter when radio assumed real proportions, this patent of almost fundamental character was infringed widely and with impunity. The use of loading coils such as contemplated in the patent by the United States Government dates from at least 1902, all without protest on the part of the owners of the patent until after the acquisition of the patent by the Marconi Wireless Telegraph Company of America on March 19, 1912. The defense of *Laches* which was found good as against this patent by His Honor, Judge Veeder, in *Marconi vs. National Electric Signaling Co.*, 213 Fed. 815,863, is applicable with increased force in the case of the United States. The Board is reluctant to apply this rule as to purchases made by the United States after the acquisition of the patent by the Marconi Company and its vigorous and prompt proceeding to protect its rights thereunder, but it is considered by the Board that the rule may be justly applied as against all purchasers made before the acquisition of title by the Marconi Company and which occurred while the then owner of the patent was asleep upon his rights. It is likely that some of these installations purchased before the acquisition of title by the Marconi Company remained in operation after such acquisition of title and that under other conditions the Marconi Company, the claimant here, might be entitled to recover for such use of those installations as occurred while the patent belonged to it. It would, however, be difficult to properly apportion such an award at this late period. The Board is proceeding on a theory of settlement based in all cases on cost price and not extent of use, the use by the Government being for the most part non-commercial and not susceptible of accurate monetary determination. It is thought that full justice will [fol. 2449] be done, recognizing the aversions of the Government to take advantage of a technical defense where it has actually used private property but also bearing in mind the above disabilities, if the award under this patent is limited in all cases to purchases occurring after March 19,

1912, dis-regarding entirely all installations which may have been made prior to that time whether they remained in use or not.

The Board has not ignored in reaching this view the fact that the patentees' right of injunction is not available against Government infringement and that up till the date of the Act of June 25, 1910, the right of recovery was restricted, but the present claimant delayed its action under that Act for over six years after its passage, the action not having been actually filed in the Court of Claims until over a year after the expiration of the patent. This delay cannot be considered as fully justified by intermediate test cases against other infringers and it is thought that sufficient justice will be done to the claimant by an allowance on the above stated basis.

Stations using dynamos or alternators as radio-frequency generators were not used by the Government prior to the expiration of the Lodge patent and thus do not appear in the accounting thereunder.

763,772, to Marconi, Granted June 28, 1904, on Application  
Filed November 10, 1900

The history of the litigation under this patent is shown in paper No. 11 of the appendix. It appears to have been uniformly sustained and the Board accepts the patent as having been sufficiently established to cover any wireless system in which at the transmitter effective transfer of energy is obtained between a closed persistent primary circuit and an open non-persistent secondary circuit, with corresponding but reversed arrangement in the receiver. The claims are limited to an open circuit radiator at the transmitter and absorber at the receiver, except claim 2 for the receiver, which, however, has as an element a tuning inductance in the antenna. These specific limitations when taken with the language of the specification, giving an effective meaning to the use of an open circuit as a quick radiator and effective absorber, and with the discussion of Judges Veeder and Neterer, would seem to exclude from the accounting to be made by the Government its various loop receiving circuits which cannot come under the term "open circuit" of most of the claims, and which do not include a variable inductance in the antenna as called for by claim 2.

Accounting, however, will be made on all systems having

open antenna whether at the transmitter or receiver coupled with a charging or receiving circuit in such manner that an effective transfer of energy takes place, from one circuit to its coupled circuit by the use of syntony, with modifications expressed below.

Note is taken of the fact that in the litigation heretofore it has not been expressly determined that transmitters employing quenched gaps, and therefore impulse excitation, are included within the terms of the patent. In the case of *Marconi vs. Kilbourne & Clark*, a circuit in which it was argued that there was no effective transfer of energy from the one circuit to the other, the two being substantially energized simultaneously, and in which at any rate there was no effective transfer from one to the other due to [fol. 2450] syntony, was held not to infringe. This, however, is not decisive of the present issue, as to the use of quenched gaps by the Government in which there is a close coupling and a slight or negligible detuning, and in which, undoubtedly, advantage is taken of syntony to secure an effective transfer of energy. The entire period covered by the claim has seen the use of structures of the class at both the transmitter and receiver, and it has taken many forms. The oscillation producer has included open gaps whether stationary or rotary and stationary quenched gaps of various forms. Also alternators of high frequency is current generators have been used in a circuit coupled to the radiating circuit.

A careful study of the various claims of this patent which have been adjudicated and held valid shows claim 10 to be broadest. This claim reads as follows:

"10. A system of wireless telegraphy, in which the transmitting station and the receiving station each contains an oscillating transformer, one circuit of which is an open circuit and the other a closed circuit, the two circuits at each station being in electrical resonance with each other and in electrical resonance with the circuits at the other station, substantially as described."

The language of this claim is on its face, broad enough to include all systems to which there are two circuits either at the transmitter or receiver and which circuits are in resonance. The only limitation is that one of the circuits must

be an open circuit. The language of this and other claims of the patent is, however, to be construed in the light of the various decisions of the courts and particularly the latest one—the only one going to an appellate court after final hearing—*Marconi Wireless Telegraph Co. of America vs. Kilbourne & Clark* rendered by the Circuit Court of Appeals for the Ninth Circuit.

The Board discusses below whether any of the Government's continuous wave apparatus where tuned coupled circuits are used, come under the patent. The most general exceptions from accounting are the Navy arc transmitters wherein the arc is placed directly in the antenna circuit and the Navy loop receivers in which there are either single circuits or, where a loop is coupled to the secondary, the combination does not include an open circuit.

Accounting will, therefore, be made on all apparatus with the exceptions noted above. But in considering quenched gap transmitters it will be borne in mind that these systems are very closely allied to the impulse excitation systems of Kilbourne & Clark and of Lodge's patent 609,154, and it may be strongly urged that much of the reasoning of the Court of Appeals in the Kilbourne & Clark case would tend to show that these systems are not equivalents of that claimed by Marconi. The specific point is not yet adjudicated, and the patent is not entitled to the weight of an adjudicated patent in this respect.

*High Frequency Alternators.* The Marconi Company was not understood by the Board to make any claim for compensation for the use of the Lodge and Marconi inventions in these sets, but the Board has of its own motion considered the subject. The question has not been found discussed in any litigation.

In considering the application of the Marconi patent 763,772 to stations having high frequency alternators as a [fol. 2451] source of oscillations, various conditions present themselves. There are three of such stations with which the Government is concerned.

The New Brunswick and Tuckerton stations need no discussion, their temporary use by the Government having been on lease from the claimant—acting in the one case on its own behalf, and in the other case as representative of the foreign owner.

The station at Sayville, Long Island, built by the Atlantic Communication Company, was seized by the Alien Property custodian, either direct or through acquiring the stock of the Company, in April, 1917. At that time the transmitter employed the High Frequency Generator with frequency transformers involved in the defense of *Kintner, et al. vs. Atlantic Communication Company*, 249 Fed. Rep. 73. The property was purchased by the Navy from the Custodian October 11, 1918. Meanwhile the station had been operated by the Navy—but the alternator referred to not having been found efficiently operative, an arc transmitter was put in service about January 1, 1918. It is doubtful whether the Government's mere ownership through the Custodian could under the circumstances be considered an infringement. Furthermore, it is very doubtful whether the system itself infringes on the Marconi patent 763,772. The alternator circuit is so closely coupled to the antenna as to be practically in the antenna. There is no reservoir action and no persistent oscillation of the alternator circuit in the sense of the Marconi patent. The amount of use was small. On the whole, the Board has not felt warranted in conceding any liability on the part of the Government in this case.

*Vacuum Tube Transmitters.* In the majority of instances, vacuum transmitters employed by the Government have had but a single circuit, the antenna being so connected to the vacuum tube elements that it comprised within itself a part of the oscillating circuit of the vacuum tube generator. In some instances, however, vacuum transmitters have had two circuits, one an oscillating circuit connected to the elements of the vacuum tube and the other an antenna circuit, and where two circuits are so employed, they are in general in tune with each other. The Board is of the opinion, however, that a continuous wave transmitter of this type does not come under the terms of the patent in that no "reservoir action" enters into the principle of exciting the antenna. The oscillations are not damped but continue in constant amplitude and the transfer of energy takes place each cycle without there being any necessity for considering the matter of storing energy in a reservoir circuit to be slowly drawn upon by an antenna or open circuit.

For these reasons the Board is of the opinion that the limited instances of the employment of vacuum tube transmitters having coupled tuned circuits are not cause for accounting under this patent.

893,684, to Fleming, Granted November 7, 1905, on Application Filed April 19, 1905

This is the well-known "Fleming valve patent" which was sustained by Judge Mayer in the suit against the DeForest Radio Tel. & Tel. Co., 243 Fed. 560. Are further proceedings in this litigation are related in paper No. 11 in the appendix. It may be noted that by the later decisions of Judge Mayer on hearings on supplemental bill, the patent was held to include the DeForest amplifier and oscillion—[fol. 2452] the original decision having held infringement as to the DeForest audion used as a detector. Proceedings are now being had before the master and it has been represented to the Board that an effort is being made by the defendant to exclude from the accounting and take out of the effect of the decision certain types of three-electrode tubes adapted particularly for certain purposes and claimed to operate on a different principle from that on which the tube of the Fleming patent operates.

Basing its action upon the decisions of the Court heretofore rendered, and which go into the matter so fully that it is unnecessary for the Board to express it, the Board will tentatively include in the accounting, subject to any later exclusion therefrom, by the final award in the above suit, of certain types of apparatus, all so-called vacuum tube detectors, amplifiers and oscillions, irrespective of the pressures used.

The Fleming patent includes not merely the tube structure, but the connecting circuits. But the tubes and the circuit are not essentially different from the corresponding parts in the Edison patent 307,031 of October 21, 1884. The novelty claimed lies rather in the application of the invention to radio frequencies than in any particular construction of the tubes or arrangement of the circuits.

The purchases by the Government are largely of tubes independent of the circuit. It is difficult to determine when the tubes were used or in what particular circuits they have been placed. Considering that the use contemplated involved the sooner or later association of the tubes in circuits to constitute the infringing combinations of the patent, the Board has concluded that the award as to these purchases of tubes should be based on their purchase price without undertaking the impossible task of tracing them to the circuits in which they—or some or them—were actually used.

In view of the disclaimer filed by the Claimant on November 17, 1905, tubes in systems employing only low frequency will be omitted from accounting.

[fol. 2453] CLAIMANT'S EXHIBIT No. 121

IN THE COURT OF CLAIMS OF THE UNITED STATES

MARCONI WIRELESS TELEGRAPH COMPANY, *Plaintiff*.

VS.

UNITED STATES, *Defendant*

Interdepartmental Radio Board's Letter of April 16, 1921  
Luella F. Little, *Notary Public*.

Interdepartmental Radio Board

2344 New Navy Building,

Washington, D. C.

April 16, 1921.

Messrs. Sheffield & Betts, 52 William Street, New York,  
N. Y.

Attention Mr. L. F. H. Betts

SIR:

*Claim No. 2--Marconi Wireless Telegraph Co.*

Referring to your conference with the Board on Apr. 7 and your further conference with Mr. Knight of the Board on April 13 in the matter of the above claim, the Board has decided that it can not make any change in its method of accounting such that due weight will not be given the Lodge patent after its expiration in 1915. The Board believes its position in this respect is sound and the only one that should be followed.

It is realized, however, that you are not interested in the method of accounting adopted by the Board provided it arrives at a figure which will be acceptable to your clients, but unfortunately the Board can not be governed in its methods by the indifference of claimants as to such methods, but feels that they must be founded on the rules laid down by the courts in patent accountings.

A review of the accounting shows that the weight given by the Board to the Arco-Rendahl patent on quenched gaps, owned by the Government, reduced the allowance to your clients by \$194,967.20. The Board is willing to revise its accounting so that this patent is not considered, which additional sum would increase the recommended allowance to your clients to \$1,253,389.02.

[fol. 2454] The Board has found that its settlement with others on the contracts in which your clients had warranted the Government amounts to approximately \$75,000.00. In other words, this amount should be added to the amount above to arrive at the total value to your clients of this proposed settlement, or \$1,328,389.00.

You intimated to Mr. Knight that you are prepared to recommend to the committee of the Marconi Company handling this claim that it accept a figure equivalent to 5 per cent of the cost of apparatus involving some or all of the Marconi Company's patents. You handed to Mr. Knight a sheet showing that you had estimated the cost of apparatus to be \$28,425,413.79, and that 5 per cent of this sum is \$1,421,270.68. A review of the Board's accounting shows that your estimated cost of apparatus is in error, the actual figure being \$26,399,490.60, 5 per cent of which is \$1,319,974.53.

It is believed that you arrived at your figure from the data listed on page 3 of your brief of Feb. 2, 1921, when you were heard by the Board. It is pointed out that in the item of "Arc Transmitters", more than two million dollars of this amount involved apparatus purchased after the expiration of the Lodge patent, which amount is practically equivalent to the discrepancy between your figures and the Board's figures.

Reviewing the above, it is pointed out that the Board's herein-proposed recommended allowance plus the saving on warranted contracts is in excess of a 5 per cent allowance on the total cost of apparatus involving the Marconi Company's patents by approximately \$9,000.00.

It is suggested that you submit this revised proposed recommendation to the committee of your clients at an early date. If acceptable, the Board's recommendation to the several heads of department will be an award to the Marconi Telegraph Company of \$1,253,389.02.

Very respectfully, E. H. Loftin (Signed) Lieut. Commander, U. S. N., Chairman.

No. 767,984.

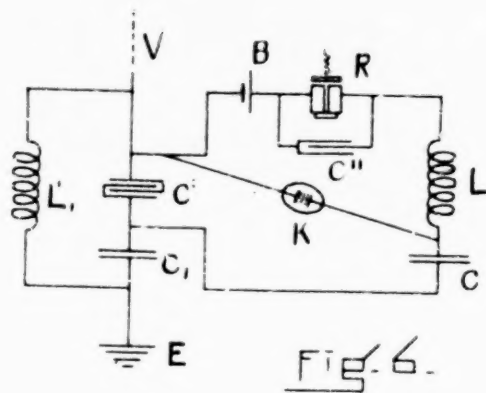
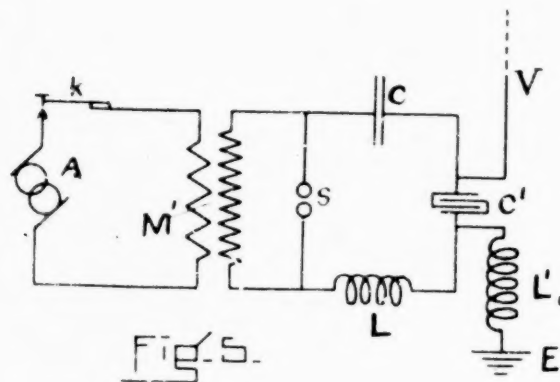
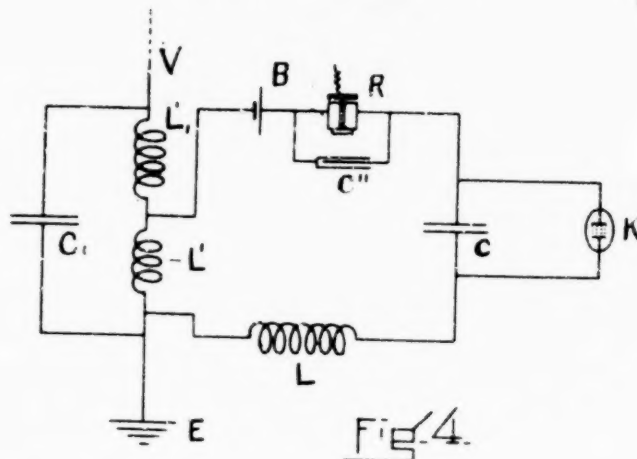
PATENTED AUG. 16, 1904.

J. S. STONE.  
SPACE TELEGRAPHY.

APPLICATION FILED NOV. 25, 1903

NO MODEL.

2 SHEETS-SHEET 2.



WITNESSES.

*Edward J. Johnson*  
*Edw. B. Johnson*

INVENTOR.

*John Stone Stone*

No. 767,984.

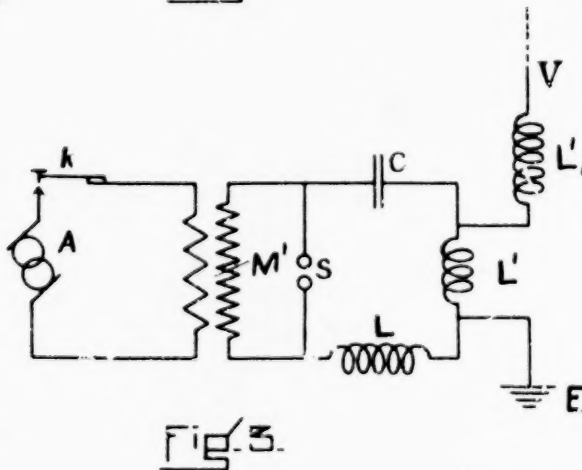
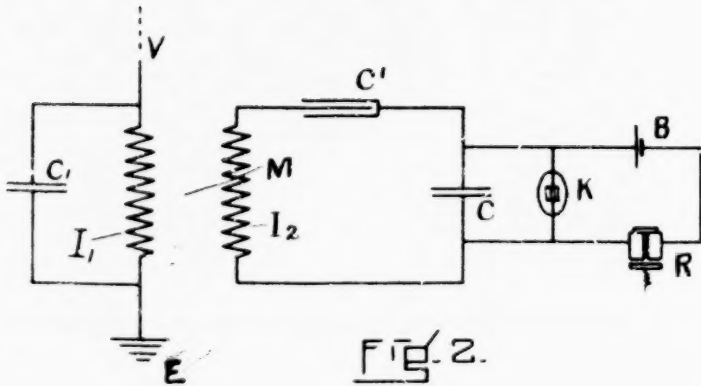
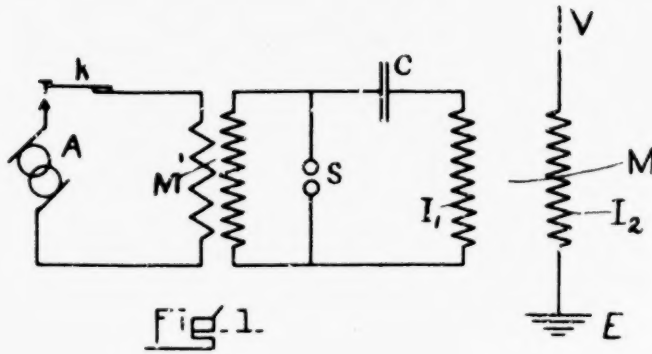
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APPLICATION FILED NOV. 25, 1903.

NO MODEL.

2 SHEETS—SHEET 1.



WITNESSES.

Braun & Quaker  
Patent Attorneys

INVENTOR.

John S. Stone

# UNITED STATES PATENT OFFICE.

JOHN STONE STONE, OF CAMBRIDGE, MASSACHUSETTS, ASSIGNOR TO  
WILLIAM W. SWAN, TRUSTEE, OF BROOKLINE, MASSACHUSETTS.

## SPACE TELEGRAPHY

SPECIFICATION forming part of Letters Patent No. 767,984, dated August 16, 1904.

Application filed November 25, 1903. Serial No. 182,832. No model.

*To all whom it may concern:*

Be it known that I, JOHN STONE STONE, a citizen of the United States, and a resident of Cambridge, in the county of Middlesex and State of Massachusetts, have invented a certain new and useful Improvement in Space Telegraphy, of which the following is a specification.

My invention relates to the art of transmitting intelligence from one station to another by means of electromagnetic waves without the use of wires to guide the waves to their destination, and it relates more particularly to the system of such transmission in which electromagnetic waves are developed by producing electric vibrations in an elevated conductor, preferably vertically elevated.

In my Letters Patent Nos. 714,756 and 714,831, dated December 2, 1902, and in other Letters Patent I have described systems of space telegraphy in which electromagnetic waves substantially simple harmonic in form are transmitted by creating substantially simple harmonic vibrations or oscillations in a sonorous circuit or system of circuits and impressing such vibrations or oscillations upon an elevated conductor. In order that the electric vibrations so impressed upon the elevated conductor, and consequently the electromagnetic waves radiated therefrom, may be simple harmonic in form, I have employed means whereby the individual circuits of a complex of interrelated circuits are made capable of vibrating as circuits of a single degree of freedom. In my Letters Patent Nos. 714,756 and 714,831, and in my Reissued Letters Patent No. 12,149, reissued August 25, 1903, I have described and broadly claimed means whereby such complex of interrelated circuits may be reduced to the equivalent of a number of circuits having a single degree of freedom. I have also specifically claimed therein one of the means whereby this result may be accomplished. The means broadly described and claimed consist in providing each circuit with sufficient auxiliary inductance to render the mutual inductance between it and an associated circuit small compared to the square root of the product of the inductances of the circuits.

The specific means therein claimed was an auxiliary inductance-coil in each circuit, whereby the mutual inductance between said circuit and an associated circuit is rendered small compared to the square root of the product of the inductances of the two circuits. Another specific means whereby the same result is accomplished is fully set forth by me in my Letters Patent Nos. 714,832 and 714,833, dated December 2, 1902, wherein I have shown that the function of the auxiliary inductance-coil may be performed by the primary of the transformer connecting the sonorous circuit with the elevated conductor by so proportioning said primary that it shall supply the auxiliary inductance, which in the other specific form of my invention was supplied by means of the auxiliary inductance-coil. This is accomplished by so designing the transformer that the ratio  $\frac{M_{12}^2}{L_1 L_2}$  is small compared to unity,

which is the opposite course from that in general pursued in constructing a step-up transformer, and is only resorted to in the construction of the so-called "constant-current" transformers, and it may also be accomplished in a plurality of ways set forth in my Letters Patent Nos. 717,467 and 717,515 in the art of wire telegraphy.

In the present specification I confine myself and limit my claims to one of these means, namely, that of so designing the transformer connecting two associated circuits that the

ratio  $\frac{M_{12}^2}{L_1 L_2}$  is purposely made small compared to unity. In other words, the means herein claimed whereby the complex of circuits is reduced to the equivalent of a system of circuits each of a single degree of freedom is different from that previously claimed by me

in that the ratio  $\frac{M_{12}^2}{L_1 L_2}$  is made small compared

to unity by making the transformer a constant-current transformer, whereas in the other patents I have claimed means for rendering this ratio small compared to unity consisting of auxiliary inductance-coils. In this case the circuits at the transmitting-station

are a sonorous circuit or closed oscillator, which is a persistently oscillating poor-radiating circuit, and an elevated transmitting-conductor or linear oscillator, which is a good radiating circuit, and therefore a poor oscillator. At the receiving-station the circuits are an elevated receiving-conductor or linear oscillator, which is a good absorbing-circuit and a poor oscillator, and a closed resonant circuit, which is a persistently oscillating circuit, and therefore a poor absorbing-circuit, except for the energy of currents of the frequency to which it is attuned. The particular means employed for reducing the aforesaid system of interrelated circuits to the equivalent of a system of circuits each having a single degree of freedom is a transformer designed as aforesaid, so that the ratio  $M^2/L_1L_2$  is made small compared to unity, so

that the transformer will have sufficient magnetic leakage to effect the desired result.

In my Letters Patent Nos. 717,467 and 717,515 in the art of wire telegraphy I have described and claimed several specific means of reducing a complex of circuits to the equivalent of a system of circuits each of a single degree of freedom. The underlying principle for accomplishing this result is in all instances that the mutual energy of each circuit with all of the interrelated circuits of the system shall be small compared with the self-energy of said circuit.

The relation of the specific invention herein to be claimed to the broad principle hereinbefore stated may be best understood by having reference to the drawings which accompany and form a part of the present specification.

In the drawings, Figure 1, 3, and 5 represent in diagram apparatus and arrangements of circuits constituting transmitting systems. Figs. 2, 4, and 6 represent in diagram apparatus and arrangements of circuits constituting receiving systems.

In the figures: V is an elevated conductor. M M are transformers.  $L_1L_1L_2$  are inductances.  $C_1C_1C_2C_2$  are condensers.  $L_1L_2$  are respectively the primary and secondary windings of the transformer M. S is a spark-gap. A is an alternating-current generator or other source of periodically-varying electromotive force. B is a battery. R is a relay. K is a receiver, herein illustrated as a coherer.  $\lambda$  is a key.

In the system illustrated in Figs. 1 and 2 the sonorous circuit S C L and the resonant circuit C' C' L are each associated with an elevated conductor V by means of a transformer M with magnetic leakage, i. e., a transformer in which the primary and secondary windings  $L_1$  and  $L_2$  have such spatial interrelation as to so reduce the mutual inductance between the associated circuits that the ratio  $M^2/L_1L_2$  is

small compared to unity, where  $L_1$ ,  $L_2$  represent the self-inductances of the associated circuits and  $M$  the mutual inductance between said circuits. It will be found that when the primary  $L_1$  is in close inductive relation with the secondary  $L_2$  and is then separated therefrom the amplitude of the oscillations developed in said secondary gradually rises to a maximum and that at this point any further separation of the transformer-windings will have the effect of decreasing this amplitude.

The operation of the apparatus shown in Fig. 1 is the same as that of the apparatus shown in Fig. 5 of my hereinbefore-mentioned patent, No. 714,756, and reference may also be had to the description of the operation of the apparatus shown in the figure of my Letters Patent No. 714,832, the function of the auxiliary inductance-coil (designated by the letter  $L_2$  shown in those drawings) being performed by the primary coil  $L_1$  of Fig. 1 of the present case. Similarly the operation of the apparatus shown in Fig. 2 is the same as that of the apparatus shown in Fig. 6 of my Letters Patent No. 714,756, the function of the auxiliary inductance-coil (designated by the letter  $L_2$  in that drawing) being performed by the secondary coil  $L_2$  of Fig. 2 of the present case.

In Fig. 3 the elevated conductor is conductively associated with a sonorous circuit S C L L'. In order to impress a simple harmonic electromotive force upon the elevated conductor V, electrical oscillations are produced in the sonorous circuit. These give rise to a corresponding difference of potential at the terminals of the inductance-coil  $L'$  in the elevated-conductor system V L' E, and corresponding forced simple harmonic electric vibrations result therein. The inductance of the coil  $L'$  being small compared to that of the coil L, the oscillations in the sonorous circuit are not materially affected by the association of this circuit with the elevated-conductor system.

In Fig. 4 the elevated conductor is conductively associated with a resonant circuit C' L L'. When simple harmonic electric oscillations are set up in the elevated conductor, a corresponding difference of potential is set up at the terminals of the inductance-coil  $L'$ , and corresponding forced simple harmonic electric vibrations result in the resonant circuit. If the frequency of these vibrations is the same as that to which the resonant circuit is attuned, said resonant circuit responds energetically and has electrical oscillations of relatively great amplitude developed in it, whereas if the frequency of these vibrations be different from that to which the resonant circuit is attuned the resonant circuit responds but feebly and has electric vibrations of relatively small amplitude developed in it. The inductance of the coil  $L'$  being small compared to that of the coil L, the oscillations in the resonant circuit

but are not materially affected by the association of this circuit with the elevated conductor.

In Fig. 5 the elevated conductor is again conductively connected to a sonorous circuit  $C' L'$ . In order to impress a simple harmonic electromotive force upon the elevated conductor  $V$ , electrical oscillations are produced in the sonorous circuit. These give rise to a corresponding difference of potential at the terminals of the condenser  $C'$  in the elevated-conductor system  $V C' L' E$  and corresponding forced simple harmonic electric oscillations result therein. The capacity of the condenser  $C'$  being large compared to that of the condenser  $C$ , the oscillations in the sonorous circuit are not materially affected by the association of this circuit with the elevated-conductor system.

In Fig. 6 the elevated conductor is conductively associated with a resonant circuit  $C' L'$ . When simple harmonic electric oscillations are set up in the elevated conductor, a corresponding difference of potential is set up at the terminals of the condenser  $C'$  and corresponding forced simple harmonic electrical vibrations result in the resonant circuit. If the frequency of these vibrations is the same as that to which the resonant circuit is attuned, said resonant circuit responds energetically and has electrical oscillations of relatively great amplitude developed in it, whereas if the frequency of these vibrations be different from that to which the resonant circuit is attuned the resonant circuit responds but feebly and has electric oscillations of relatively small amplitude developed in it. The capacity of the condenser  $C'$  being great compared to that of the condenser  $C$ , the oscillations in the resonant circuit are not materially affected by the association of this circuit with the elevated conductor.

No mention has heretofore been made of the function of the condensers  $C''$ , as these condensers are not essential to the tuning of the circuits in which they are placed, but merely serve to shunt the relays  $R$  out of the resonant circuits. In order that these condensers may not appreciably affect the tuning of the circuits in which they are included, and thereby lower the resonant rise of potential at the plates of the condenser  $C$ , they are so constructed as to have large capacities compared to the capacities of the condenser  $C$ .

No mention has heretofore been made of the function of the condensers  $C_1$  and inductance-coils  $L_1$ , as the functions of these elements have been fully described in my applications Serial Nos. 193,371 and 193,372, filed February 13, 1904, and as they form no essential part of the present invention.

I claim

1. In a system of space telegraphy, an elevated transmitting-conductor serially connected with one winding of a transformer and a

sonorous circuit including the other winding of said transformer, said windings being so spatially interrelated as to reduce the complex of interrelated circuits to the equivalent of a system of circuits each having a single degree of freedom. 70

2. In a system of space telegraphy, an elevated receiving-conductor serially connected with one winding of a transformer, and a resonant circuit including the other winding of said transformer, said windings being so spatially interrelated as to reduce the complex of interrelated circuits to the equivalent of a system of circuits each having a single degree of freedom. 75 80

3. In a system of space telegraphy, an elevated conductor serially connected with one winding of a transformer and a persistently-oscillating circuit including the other winding of said transformer, the separation of said windings being sufficient to reduce the complex of interrelated circuits to the equivalent of a system of circuits each having a single degree of freedom. 85

4. In a system of space telegraphy, a transmitting system comprising a sonorous circuit inductively associated with an elevated conductor by means of a transformer, in combination with a receiving system comprising a resonant circuit attuned to the frequency of the electric oscillations developed in said sonorous circuit and inductively associated with an elevated conductor by means of a transformer, the windings of each of said transformers being so spatially interrelated as to reduce the complex of interrelated circuits constituting the transmitting and receiving systems each to the equivalent of a system of circuits having a single degree of freedom. 90 95 100

5. In a system of space telegraphy, a good oscillator connected with a good radiator or absorber by means of a transformer having sufficient magnetic leakage to reduce the complex of circuits to the equivalent of a system of circuits each having a single degree of freedom. 105 110

6. In a system of space telegraphy, a persistently-oscillating circuit, a good radiating or absorbing circuit, and a transformer inductively associating said circuits, the mutual inductance between the windings of said transformer being sufficiently small to reduce the complex of interrelated circuits to the equivalent of a system of circuits each having a single degree of freedom. 115 120

7. In a system of space telegraphy, a persistently-oscillating circuit, a good radiating or absorbing circuit, and means for so associating said circuits that the mutual energy of each circuit with its interrelated circuit is rendered small compared with the self-energy of each circuit. 125

8. In a system of space telegraphy, a persistently-oscillating circuit, a good radiating or absorbing circuit, and means for so in- 130

ductively associating said circuits that the mutual energy of each circuit with its interrelated circuit is made small compared with the self-energy of each circuit.

9. In a system of space telegraphy, a persistently-oscillating circuit, a good radiating or absorbing circuit, and means for so associating said circuits that the complex of interrelated circuits is reduced to the equivalent of a system of circuits each having a single degree of freedom without the interposition of auxiliary means.

10. In a system of space telegraphy, a persistently-oscillating circuit, a good radiating

or absorbing circuit, and means for so inductively associating said circuits that the complex of interrelated circuits is reduced to the equivalent of a system of circuits each having a single degree of freedom without the interposition of auxiliary means.

In testimony whereof I have hereunto subscribed my name this 24th day of November, 1903.

JOHN STONE STONE

Witnesses:

G. A. HIGGINS,

BRainerd T. JUDKINS.

Correction in Letters Patent No. 767,984.

It is hereby certified that in Letters Patent No. 767,984, granted August 16, 1904, upon the application of John Stone Stone, of Cambridge, Massachusetts, for an improvement in "Space Telegraphy," an error appears in the printed specification requiring correction, as follows: On page 2, line 66, the symbol " $L$ " should read  $L$ ; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 11th day of July, A. D., 1905.

[SEAL.]

F. I. ALLEN,

Commissioner of Patents.

[fols. 2461-2462] PLAINTIFF'S EXHIBIT 122

## RADIO PATENTS

Settlement Of Claims Against Government For Use Of  
Radio Patents During The World War

Hearings

Before The

Committee On Military Affairs

House Of Representatives

Sixty-Seventh Congress, First Session

Monday, May 23, 1921

Statements of

Commander Stanford C. Hooper, U. S. N.

Lieut. Commander Edward H. Loftin, U. S. N.

Capt. Guy Hill, U. S. A.

Mr. Harry E. Knight, Department of Justice.

Mr. Edward G. Curtis, Special Assistant to the Attorney General.

[fol. 2463]

Radio Patents

Committee on Military Affairs,  
House of Representatives,  
*Monday, May 23, 1921.*

The committee met at 10:30 o'clock a. m., Hon. Julius Kahn (chairman) presiding.

The Chairman. I have called this meeting of the committee this morning to consider a letter which I received, through the Speaker, from the Secretaries of War and Navy and the Attorney General of the United States regarding the settlement for patents which the Government used during the war for the benefit of the country. They have suggested a bill for that purpose, to which I have made a slight amendment. I will ask the clerk of the committee to read the letter.

(The clerk read the letter, as follows:)

Departments of War, Justice, and Navy,  
*Washington, D. C., May 14, 1921.*

DEAR MR. GILLET: We have the honor to invite attention to the situation that exists as a result of the use by the Government of patented inventions relating to radio communication and the development in that art.

Prior to the war with Germany the Government, principally the War and Navy Departments, found it necessary, because the validity of many patents relating to wireless telegraphy had not been judicially determined, to use wireless apparatus of various kinds without strict regard to the rights claimed by patentees, and during the war both departments used any and all apparatus, principles, and methods of known value without consideration of questions of infringement or proprietorship, giving where necessary its warranty to contractors to protect them from litigation for infringement.

The development of this art has been very rapid and the patent situation with respect thereto is exceedingly complicated. There are many patents relating to the subject and a large number of claims for compensation for alleged use and infringement of patented inventions, among which there is much conflict, have been filed with the War and Navy Departments.

Realizing that the use by the Government had infringed the rights of many patentees, while some of the claims possess little or no merit, and that a fair and reasonable determination of the whole matter would be difficult, long drawn out, and expensive to the Government as well as to the claimants if an adjustment were not arrived at by a reasonable and businesslike consideration of the interests of all parties concerned, a board designated "Interdepartmental Radio Board" was appointed by ourselves consisting of experts from the War Department, Department of Justice, and the Navy Department to consider all such claims, each with reference to its own merits and the merits of all the others. Such board has been considering the matter for nearly three years, giving all questions connected therewith careful, intelligent, and exhaustive consideration.

The claims presented to the board totaled many millions of dollars. Out of the 24 claims brought only 7 stated the amount of the compensation desired, and the total of those 7 was \$14,860,000, the rest aggregating probably a much larger sum.

The board, giving due weight to matters of infringement, validity of patents, values of inventions, the circumstances of use by the Government, and the entire value of up-to-date wireless apparatus as the product of all inventions [fol. 2464] combined, has determined a sum of money that the Government should fairly and reasonably pay to the different patentees in proportion to the value of their respective inventions. Such sum will not exceed \$2,500,000, which is only a small percentage of the aggregate sum claimed.

The owners of the various patents affected have been informed of the board's determination, and many or all of them have signified a willingness to accept the amounts allotted to them. The work of the board has been most painstaking and careful, and its conclusions and determinations reflect great credit upon its members. If settlement with the various patentees can be effected on the basis of the board's determination, a situation fraught with troublesome consequences would be disposed of to the great advantage of the Government and to the ultimate satisfaction of the claimants, and it is highly desirable, therefore, that provision be made for such settlements.

Therefore it is urgently recommended that the War, Justice, and Navy Departments be empowered to adjust and pay said claims on the basis of said board's determination.

Transmitted herewith is a draft of a provision that it is believed covers the matter adequately, and is suggested as an amendment to the act entitled "An act to provide relief in cases of contracts connected with the prosecution of the war, and for other purposes," approved February 2, 1919, commonly known as the Dent Act.

If at an early date payment could be tendered to all the claimants of the respective amounts found in their favor by said board, it is believed that all claimants having claims of substantial merit would accept settlement and release the Government, and it is earnestly requested that this

matter be given favorable and prompt consideration by Congress.

Very sincerely, John W. Weeks, *Secretary of War*,  
H. M. Daugherty, *Attorney General*, Edwin Denby,  
*Secretary of the Navy*.

Hon. Frederick H. Gillett, *Speaker of the House of Representatives*.

(The bill above referred to is as follows:)

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the act entitled "An act to provide relief in cases of contracts connected with the prosecution of the war, and for other purposes," approved February 2, 1919, and the same is hereby amended by adding thereto the following section:

"Sec. 6. That the Secretary of War, the Attorney General, and the Secretary of the Navy, acting jointly or severally, as in their judgment the circumstances of each case may require, are hereby authorized to adjust, pay, and discharge any and all claims against the United States for or on account of the use or manufacture by or for the United States of any patented invention relating to radio communication in cases in which such patented invention was used without agreement with the owner as to compensation therefor, such settlement of claims to cover both past (whether prior to, during, or after the war) and future use where practicable in all cases, and to be based on the determination by such agency as the said Secretaries and Attorney General have designated or established or may designate or establish of all questions of infringement, validity of patents, and value of inventions: *Provided*, That this provision shall not be so construed as to deprive owners of patents who shall not accept settlement under this act of any rights of action conferred by the acts for protection of the owners of patents, approved June 25, 1910, and July 1, 1918, respectively, and for the payment of such claims the sum of \$2,500,000, or so much thereof as may be necessary, is hereby appropriated out of any money in the Treasury not otherwise appropriated."

The Chairman: I have asked the officers representing these three departments to come before the committee this morning for the purpose of explaining the matter to us. I

understand that officers representing the Navy Department will make the opening statements, and we will be very glad to hear them.

[fol. 2465] Statement of Commander Stanford C. Hooper,  
Officer in Charge, Radio Division, Bureau of Engineering,  
Navy Department

Commander Hooper: Mr. Chairman, the application of radio-telegraphy for practical purposes is but 20 years old. It is highly scientific, most intricate, and because it is the only practicable means of communication where land wires are not possible, it is most valuable for military purposes. Its growth in these 20 years has been marvelous, of such rapidity that if the military services were to make quick application of the various developments in order to keep abreast of competing nations, there was no time, with the limited skilled force available both in the military branches of the Navy and the Patent Office, to pay proper attention to the patent side of the art.

Today approximately one-tenth of the cable business of the world is being handled by radio. Great improvements in signaling the fleets has been made so that flag commanders are able to give an order on the bridge of the flagship to cause their fleets to turn right and left or about, almost instantly by radio signaling. Prior to this application, maneuvering by flag signaling was slow and uncertain, due to smoke and distance obscuring the flags. Similarly an airplane flight commander is able to telephone by radio his orders for maneuvering his squadrons of airplanes. By virtue of radio the heads of departments on shore are able to give orders to the fleets and individual ships in any part of the world by our wireless system at great increase of efficiency and great saving of cable tolls. Admirals at sea are able to spread their scouts out at great distances apart, keeping in touch by radio, whereas formerly they must cruise in limited area in order to sight each other and make reports at definite time intervals. This decreases the number of ships required for scouting. The spotting of fleets and of shore batteries has been increased in efficiency hundreds of per cent due to spotting by aircraft which locates the fall of shots with great accuracy due to better observation methods, which would be impossible were it not for the radio with which to communicate the fall of shots.

By means of radio compass instruments, or radio direction finders, it is possible to get an accurate bearing of any ship or station which is transmitting by radio. The Navy has installed for naval ships and for mercantile ships in addition some 70 radio lighthouses on the Atlantic, Gulf, and Pacific coasts, by means of which ships at sea are able to merely call up these stations, and within five minutes be given accurate positions of their locations. This is of greatest assistance to navigation in rainy or foggy weather and the saving of many ships from grounding, and expediting others in reaching a port, whereas, due to fog, etc., they might be delayed for days. Similarly aircraft are aided in reaching their landing fields, where in foggy weather this might be impossible without great risk. The Navy is handling about 60,000,000 words a year in radio traffic. Last year the amount of tolls saved to the Government by means of the Naval Communication Service was in the neighborhood of \$7,500,000.

This summary is merely for the purpose of showing that the application of radio is bringing the Government great value in a financial way, as compared to expenditures made for this service.

[fol. 2466] To date there has been no radio company which has reaped great profit from its patents, through which these various developments have been made. In fact, practically all the profits have gone into new developments and new construction, and most of these profits have been purely manufacturing profits.

Two or three times before the war efforts were made to commence the clarification of the complicated radio patent situation in order that royalties should be arranged for to the various companies which owned radio patents. Each time has brought down to the Government department an avalanche of inventors with so many overlapping patents that it was found impossible to determine just who owned the different patents and what the royalties should be. There was no personnel in any Government department capable of handling this matter.

The war came on, and it was universally agreed among the radio companies that they would put aside patent matters until the war was over and give the Government free hand to proceed as best it could to purchase apparatus. This the Government did and with the good will and cooperation of all.

After the war, conferences were arranged between the various departments of the Government interested, principally the War, Navy, and Justice Departments, to discuss methods whereby remuneration might be given those who were justly entitled to royalties on radio apparatus purchased by the Government. The ultimate result was the forming of an interdepartmental radio board, which has for two years constantly been in session with a view to adjusting this matter.

The general policy which governed the board was, first, justice to all concerned; second, the desire to increase incentive to inventions and advance the Government's position in the art of radio telegraph; third, economy for the Government; and fourth, an arrangement for prompt recompensation to all parties.

A list of radio patents purchased by the Government has been compiled, and a list of radio apparatus purchased has been compiled, and the board has worked out a plan to reimburse inventors. In all there are about 500 patents, and that number has been reduced to about 27. That has been accomplished through negotiations with the claimants, and the value of the claims has been reduced to about \$2,500,000.

Lieut. Commander Loftin, who has been the head of the board, can give you full information in reference to the board and its method of arriving at its recommendations.

The Chairman: We would be glad to hear the lieutenant commander.

Statement of Lieut. Commander Edward H. Loftin, assistant to the Officer in Charge of the Radio Division, Bureau of Engineering, Navy Department, in Charge of the Patent and Research Sections, with Additional Duty as a Member of the Interdepartmental Radio Board.

Commander Loftin: Mr. Chairman and gentlemen of the committee, I think the first matter I will call to your attention is the authority under which the Interdepartmental Radio Board has been acting, and we have that in the form [fol. 2467] of a precept from the Secretary of War, the Attorney General, and the Secretary of the Navy.

The Chairman: When was that issue?

Commander Loftin: This precept was not issued until February 12, 1921. The reason for that was that that board was informally brought together by orders from the heads

of each of the departments to its own representatives, ordering them to meet with such a board. In our proceedings we found that the situation was quite embarrassing in that we often had inquiries from various claimants as to what our authority was, and what authority we were going to show when we reached our conclusions for having acted as such a board. So we then reported to the several heads of the departments our embarrassment and asked them to give us a formal precept.

Mr. Morin: When were the members of the board originally brought together?

Commander Lortin: The members of the board were originally brought together in August, 1918. Nothing was acted upon until February, 1919. The officers who were originally made members of that board all had duties in the departments. It was during the period of the war, and it was practically impossible for them to undertake the consideration of a situation such as this was.

The Chairman: You mean that the officers representing the Navy all had duties under the Navy Department?

Commander Loftin: Yes, sir; and the officers representing the War Department all had duties under the War Department.

The Chairman: What about the representatives of the Department of Justice?

Commander Loftin: At that time there was only one attorney in the Department of Justice handling patent matters. There were many suits pending against the United States, and he was thoroughly occupied at that time.

Mr. Morin: Has not this board been conducting its business with the approval of the three members of the Cabinet, heads of these three departments, War, Justice, and Navy.

Commander Loftin: Yes, sir; this request was signed by the three members of the Cabinet representing these three departments. The precept says:

Whereas the operations of the War Department and the Navy Department during the war, relating to the furnishing of adequate supplies for radio communication, developed the fact that the patent rights of greatly needed supplies were diversely held, which rendered quantity production by the employment of all the available manufacturing facilities difficult, which situation made obvious the neces-

sity for proceeding with production, without regard to the existence of patent rights, orders for which procedure were issued by both departments, wherein the United States Government directly assumed responsibility for the proper compensation for the unauthorized use of patent rights; and

Whereas large claims were presented to the United States flowing out of such procedure, in addition to others which already had accumulated, and for which suits had been filed against the United States in the Court of Claims; and

Whereas the situation thus produced made obvious the advisability of creating a board of experts in patent law and radio science for the purpose of determining scientifically the measure of liability in which the Government became involved; and

Whereas the Secretary of War suggested the creation of such a board to the Secretary of the Navy and the Attorney General, in which suggestions they concurred, and out of [fol. 2468] which was created by separate appointment representatives of the Secretary of War, the Secretary of the Navy, and the Attorney General, to constitute the Interdepartmental Radio Board, which board has been heretofore organized and has made considerable progress in the discharge of the duties the problems presented seemed to require

Now, therefore, it is directed that the officers and representatives of the several departments heretofore appointed, to wit: Commander Stanford C. Hooper, United States Navy, and Lieut. Commander Edward H. Loftin, United States Navy, representing the Navy Department; Capt. Guy Hill, United States Army, and Robert H. Young, Esq., representing the War Department; Harry E. Knight, Esq., representing the Department of Justice; and any successors of any of said members who shall hereafter be from time to time appointed shall continue as a board, designated the Interdepartmental Radio Board, to investigate, hear, and examine the questions relating to the liability involved in the use by the Government of patents on radio apparatus and similar devices and render to the several heads of the departments mentioned their conclusions and recommendations therein.

Such assistance and information as the board may require will be rendered to it by the officers of the respective departments familiar with patent and technical matters involved in those departments.

Newton D. Baker, *Secretary of War*. Josephus Daniels, *Secretary of the Navy*. A. Mitchell Palmer, *Attorney General*.

To Interdepartmental Radio Board, *Navy Building, Washington, D. C.*

Washington, D. C., *February 12, 1921.*

The Chairman: As I understand it, from the reading of that precept, the Government practically asked these inventors to allow the Government to use their patents, they ultimately to look to the Government for pay for these inventions. That was the purpose of this precept, was it not?

Commander Loftin: Of this order?

The Chairman: Yes.

Commander Loftin: The negotiations were really instigated by several of the main patent holders. During the war we insisted that in all litigation in reference to these patents that the Government was interested and litigation should cease. A number of letters were written to the district courts practically saying that the Government would not tolerate the continuance of litigation on radio patents during the war, and a number of those cases were—in fact, in three cases in which we took such action the cases were set over. The real purpose of that was this: Litigation requires the attention of the engineers of the companies. We had taken a number of the engineers into both services for war purposes, and those who remained with their companies were urgently needed in the production and development of radio apparatus for use during the war.

The Chairman: Was that notice to the inventors in writing?

Commander Loftin: It was to the courts; I am not certain about that; I think we can produce some letters to the companies.

The Chairman: Will you kindly do that and put them in the hearing for the benefit of the members of the committee?

Commander Loftin: I will do that, sir.

[fol. 2469] (The letters referred to are as follows:)

Interdepartmental Radio Board,  
Washington, D. C., May 25, 1921.

Hon. Julius Kahn, *Chairman Committee on Military Affairs, House of Representatives, Washington, D. C.*

SIR: Referring to my hearing before the committee on May 23 in connection with the proposed amendment to the Dent Act for the settlement of claims against the Government under patents in the art of radio communication, I am inclosing copies of a number of Navy Department letters which show the department's policy in the matter of suspending litigation on radio patents during the war. This is done in accordance with your request after my reference during the hearing to this particular policy.

Very respectfully,

Edward H. Loftin, *Lieutenant Commander, United States Navy, Chairman.*

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January 18, 1918.

GENTLEMEN: From information received by the department from the Bureau of Steam Engineering, it appears that the Government's interests are indirectly involved in the suit of the New York Patents Exploitation Co. against the Mallery Steamship Co., on account of alleged infringement of the Seibt patent, No. 1216615, relating to quenched spark radio apparatus, and that certain information of record in the department or within the knowledge of experts in the department's employ will be of considerable value in connection with the trial of said cause.

In view of the demands made on the entire force of the department's employees under existing conditions, it is not possible that the Government's interests, as affected by said suit, can be given the attention requisite to a proper disposition of the matters in issue, and, as the department's interests will be affected by the outcome of the case analogously with those of the defendant, it is requested that you,

in the public interests, ask the court to stay all proceedings for the duration of the war.

Very respectfully,

Franklin D. Roosevelt, *Assistant Secretary.*

Messrs. Sheffield & Betts, *Counselors at Law, 52 William Street, New York City, N. Y., Attorneys for Mallory Steamship Co.*

April 27, 1918.

GENTLEMEN: The bureau has received information that you are pushing the suits against E. J. Simon and the Kilbourne & Clark Co. It is believed to be in the interests of the Government to have this litigation stopped.

Please inform the bureau what arrangements you propose to make.

Very respectfully,

H. P. Le Clair, (By direction Chief of Bureau.)

Marconi Wireless Telegraph Co., *Woolworth Building, New York, N. Y.*

December 14, 1917.

Attention of Mr. E. J. Nalla.

GENTLEMEN: The bureau has received information that the patent suit pending against the Government is being pushed by the Marconi Co. You are undoubtedly aware of the fact that in order to defend itself properly, many of the radio experts now with the Government would be required as witnesses for the defense. In view of the fact that we are now prosecuting a war which requires constant attention of all the Navy's experts, it would be impossible for them to take time away from their other important [vol. 2470] work to testify in this case. Thus an injustice would be worked the Government. It is hoped therefore, that the Marconi Co. will be able to see its way clear to a postponement of this suit until after the present war.

Very respectfully,

R. S. Griffin, *Engineer in Chief, United States Navy, Chief of Bureau.*

Marconi Wireless Telegraph Co., *Woolworth Building, New York, N. Y.*

April 7, 1917.

From: Bureau of Steam Engineering.

To: Solicitor.

Subject: Suspension of patent suits during war.

1. There are a number of radio patent suits now in the courts and in prospect which the department is either directly or actively interested in, the principal one being a suit by the Marconi Wireless Telegraph Co. filed in the Court of Claims against the Government. It is impracticable under present conditions, owing to the rush of work, for the bureau to devote any attention to these matters of litigation without taking the attention of the experts from the efficient conduct of its duties in providing and supplying radio sets to the fleets. It is therefore recommended that suitable arrangements be made whereby all litigation of the nature described above be suspended until after the war.

Griffin.

July 11, 1918.

Sir: From information received by the department from the Bureau of Steam Engineering it appears that the Government's interests are involved in the suits of Samuel M. Kintner and Halsey M. Barrett against the Atlantic Communication Co. on the re-issue patent No. 12168 and patents Nos. 1050441 and 1053728, relating to the so called heterodyne and sustained wave, now pending before Judge E. Henry Lacombe as master, and that it may be found advisable for the department to intervene and to furnish information and testimony in said matter.

In view of the demands made on the entire force of the department's employees under existing conditions, it is not possible that the Government's interests as affected by said suit can be given the attention requisite to a proper disposition of the matters in issue, and as the department's interests may be affected by the outcome of the case, it is requested that you, in the public interest, ask the court to stay all proceedings for the duration of the war.

W. S. Benson, *Acting Secretary of the Navy*.

Mr. Dean S. Edmonds, 35 Nassau Street, New York, N. Y.

August 23, 1918.

SIR: Replying to your letter of July 30, 1918, on the subject of the suit between the American Telephone & Telegraph Co. and Mr. Peter Cooper Hewitt.

The suit is apparently not a patent infringement suit and probably does not directly involve wireless. It is further appreciated that you would not under any circumstances press a suit that might embarrass the Government to the slightest degree in the prosecution of the war.

In view, however, of the far-reaching effect of a decision unfavorable to the American Telephone & Telegraph Co. and the importance which they would naturally attach to a proper defense of the suit this bureau is of the opinion that it would be necessary to call upon experts who are now employed on important war work, and that this would necessarily be very objectionable to the Government.

For this reason it is believed inadvisable for the Government to withdraw or modify its request to Hon. Julius M. Mayer to have the suit postponed. The request of the [fol. 2471] Government, however, is not to be construed as making it unnecessary for the telephone company's counsel to use every effort to obtain the services of satisfactory experts who are free to undertake the work.

Very respectfully,

R. S. Griffin, *Engineer in Chief, United States Navy,*  
*Chief of Bureau.*

Mr. Drury W. Cooper, *55 Liberty Street, New York, N. Y.*

July 20, 1918.

Sir: This department is informed that a suit is pending before you in which Peter Cooper Hewitt is claiming that the vacuum tubes furnished by the American Telephone & Telegraph Co. embody certain inventions owned by him, and that you desire to be informed as to whether or not the experts available to the American Telephone & Telegraph Co. for consultation and presenting the situation to the court are free to take up this work, or whether, on the contrary, their services are required by the Government.

For the war necessities now existing this department requires and is obtaining the services of all of those who are skilled in vacuum-tube matters in the organizations of the American Telephone & Telegraph Co. and of the Western

Electric Co. (Inc.), as well as those connected with other organizations. It would be prejudicial to the public interests to permit anyone having such knowledge of the operation of these devices in telephony and allied work as would fit him to assist the court and the defendant in the presentation of this case to devote to the case the time which would be necessary for this purpose.

Moreover, the experts of the American Telephone & Telegraph Co. and of the Western Electric Co. (Inc.) and others are engaged in cooperation with this department in highly confidential work involving vacuum-tube operations along lines deemed to be of the highest importance in connection with the prosecution of the present war. This work must be proceed; any testimony given by persons having knowledge of this confidential work, even though not specifically directed to it, would be inadvisable.

For these reasons this department requests that no further steps be taken in this litigation during the present emergency.

Copies of this letter are being forwarded to Mr. Drury W. Cooper and Mr. Charles Neave.

Respectfully,

Josephus Daniels, Secretary of the Navy.

Hon. Julius M. Mayer, United States District Court, New York, N. Y.

January 18, 1918.

Gentlemen: From information received by the department from the Bureau of Steam Engineering it appears that the Government's interests are indirectly involved in the suit of the National Electric Signalling Co. against the Marconi Wireless Telegraph Co., of America, on account of alleged infringement of two patents to Reginald A. Fessenden, Nos. 918306 and 918307, covering improvements in high group frequency radio apparatus, and that certain information of record in the department or within the knowledge of experts in the department's employ will be of considerable value in connection with the trial of said cause.

In view of the demands made on the entire force of the department's employees under existing conditions it is not possible that the Government's interests as affected by said

suit can be given the attention requisite to a proper disposition of the matters in issue and as the department's interests will be affected by the outcome of the case analogously with those of the defendant, it is requested that you, in the public interest, as the court to stay all proceedings for the duration of the war.

Very respectfully,

Franklin D. Roosevelt, Assistant Secretary.

Messrs. Sheffield & Betts, Counsellors at Law, 52 Williams Street, New York City, N. Y., Attorneys for Marconi Wireless Telegraph Co.

[fol. 2472]

April 20, 1918.

Sir: I had the honor to address you under date of February 13, 1918, in regard to the suit of the International Radio Telegraph Co. (formerly S. M. Kintner and H. M. Barrett, receivers of the National Electric Signaling Co.) against Marconi Wireless Telegraph Co., now pending before you in the United States District Court for the District of New Jersey. In this letter it was stated:

"The department does not wish to be understood as requesting a stay of proceedings that would interfere with the making up of the record up to the point where testimony of Government witnesses already of record is incorporated in the case, but in view of the stress of present activities of the department, the absence of some of its experts in foreign waters, and the heavy burden of duties now engrossing the entire time of others, it is believed that the Government's interests would be materially prejudiced, unless given the opportunity after the termination of the war to have incorporated into the record such further testimony as it may deem appropriate and relevant to the patents in suit."

It is the understanding of the department that the record in this case has been now made up to the point where testimony of Government experts already of record has been incorporated therein, but in view of the stress of present activities of the department and the absence of some of its experts in foreign waters and the heavy burden of duties now engrossing the entire time of others, it is believed that the Government's interest would be materially prejudiced, unless given the opportunity after the termination of the

war to have incorporated into the record such further testimony as it may deem relevant and proper to the patents in suit. Hence, it is for the public interest that further proceedings in this cause be suspended for the duration of the war.

Josephus Daniels, Secretary of the Navy.

Commander Loftin: Mr. Chairman, I will take up the general situation first, and then I think the details can be brought out by questions put to me and other members of the board who have been working on this proposition for several years.

Congress and the heads of the several departments are not interested directly in the details of the hundreds of patents which have been considered by this board, and must, of necessity, abide by the opinion of this board or any similar organization; but they are interested in what, in fact, is accomplished by such a board.

There are approximately 2,500 United States patents in this art, all of which were living during the period covered by the board. All of these have had to be considered in one way or another; if not directly as patents under which claims are made, then as to their bearing on patents under which claims were made. In addition, hundreds of foreign patents and hundreds of United States and foreign publications have been sought out and considered in relation to their effect on those patents presented in the claims.

The claimants did not know precisely just what the Government had used, and many of them brought claims under all patents, with the result that the board had to laboriously proceed through several hundred patents, pick out those under which it was evident there was no infringement, and then by hearings with claimants, long drawnout, eliminate the chaff.

The board finally came down to a real serious consideration of 149 patents. This consideration involved searches of the art, writing of long reports, receipt of briefs from claimants, hearings, more briefs, revised reports, and then an accounting on those patents considered good, which were 27 in number, with much discussion following as to the methods of accounting and the effect of decisions thereon.

[fol. 2473] The final number of patents found by the board to be of substantial value was 27. This does not mean there

were not other patents which had been used in small ways, but most of the claimants, recognizing the scope of such an investigation, and realizing that it would draw out the investigation to such an extent by considering minor patents, agreed in advance, if they succeeded in getting a settlement on some of their basic patents, that they would then lump them all and release to the Government all minor patents.

The Chairman: Of these 2,500 patents claimed, were a goodly number allowed before the board was organized?

Commander Loftin: Allowed where?

The Chairman: Or approved by the Government as being valid patents?

Commander Loftin: They were allowed by the Patent Office; yes, sir.

The Chairman: About how many of those patents were there, of the 2,500 that were allowed?

Commander Loftin: Actually about 2,500 were allowed by the Patent Office, but only 27 major patents were allowed by the board as having been used by the Government. We were not asked to consider some minor patents; they were thrown in, if settlement could be reached on the major patents.

Mr. Parker: That is to say, there were minor patents owned by the owners of the major patents?

Commander Loftin: Yes, sir.

Mr. Parker: Then there were a lot of outside patentees who were getting nothing under this settlement?

Commander Loftin: We have asked practically everybody who was suspected of owning a radio patent to come before the board and present evidence.

Mr. Parker: Will they all be released?

Commander Loftin: They will be released, those that have been favorably considered by the board.

Mr. Parker: There are a number which have not been favorably considered; are they going to be released?

Commander Loftin: Most of them will be included in the releases, along with the major patents. For instance, the Marconi Co. has about 350 patents. They presented only four patents finally to the board. The board allowed three of those four patents. They will include in their release to the Government all of the 350 patents that they own, and also the one not allowed by the board, so that it will be a complete and sweeping release of that company on practically 350 patents.

Mr. Parker: What about the Deforest Co.; that was a rival company?

Commander Loftin: We have not succeeded in reaching a settlement with the Deforest Co. In 1917 the Deforest Co. sold to the American Telephone & Telegraph Co. the exclusive rights under their patents. Most of the apparatus bought, which was covered by those patents was bought during the war; if it was prior to the war it was bought from Deforest himself, so there would be practically no allowance to Deforest prior to the time he made this sale to the American Telephone & Telegraph Co. He has contended that he [fol. 2474] has a claim subsequent to such transfer to the American Telephone & Telegraph Co. That matter was submitted to the Attorney General by the board for an opinion as to whether or not he had a legal claim. So far he has failed to convince the Department of Justice that he did have a legal claim. He had many hearings there, and he finally decided that the question involved was so difficult that he would withdraw his claim from the board and submit it to the Court of Claims, later on, if he so desired. So he stands now with his claim withdrawn from the board on a technical, legal question.

Mr. Parker: Can we not force him into the Court of Claims so that we can have done with the question for good?

Commander Loftin: There is no necessity to force him into the Court of Claims; he will go there if he thinks he has any substantial claim.

The Chairman: In the draft of the bill which the departments sent to me I have suggested to one or two of my colleagues on the committee, with whom I have talked, that we put a limitation in there compelling them to present all their claims within a comparatively short length of time, or lose their rights altogether, and that is the only way to handle the question, otherwise the matter would be pending for years, and no committee of Congress at this time wants that kind of a condition to prevail.

Commander Loftin: I might add here that we have already obtained a release from the American Telephone & Telegraph Co. for all claims that they have on the Deforest patents, under which they acquired exclusive rights on March 17, 1917.

The Chairman: About how many claims are included in this bill out of the 2,500 patents that were filed?

Commander Loftin: This will settle all claims which have been presented to the board, except that of the Deforest Co., which has been withdrawn, and one or two minor claims, which were not found by the board to have substantial merit.

The Chairman: What was the value of the Deforest claims as presented by them?

Commander Loftin: He has filed suit in the Court of Claims in which he puts the value at \$2,000,000.

The Chairman: So then, as I understand you, claims to the value of \$14,000,000 in the aggregate, or thereabouts, were filed with you. Of that \$14,000,000 how much is unrepresented in the report you now make?

Commander Loftin: Deforest has \$2,000,000, and there is one other claim for \$150,000.

The Chairman: So that in making a settlement of these claims and paying \$2,500,000 you are practically wiping out approximately \$12,000,000 worth of claims?

Commander Loftin: But that \$14,800,000 only represented the statements of 7 out of 24 claimants. The other 17 did not state any particular sums, or have not filed suits in the Court of Claims from which we could arrive at figures.

The Chairman: Then you assume that the \$2,500,000 which you propose to be paid in settlement, will cover a much greater value than \$14,000,000?

Commander Loftin: Easily double that.

[fol. 2475] The Chairman: You may proceed.

Commander Loftin: Such a task has been stupendous, and has required a force of experts—expert to begin with, but which became more expert daily in its specific task as it gained knowledge from experience.

Consider the chaos that would have existed if such a task (the serious consideration of 149 patents of a difficult art) had been presented to a number of courts in different places and at different times; for a single patent could be the cause of half a dozen suits in order to reach the numerous contractors for the Government; and then, after the patents had been sustained, the long drawn out procedure of accounting in each case, each accounting duplicating in many respects accountings in other jurisdictions.

I predict that under our judicial system, and with the extreme difficulty in presenting patent cases, that the task could not have been covered in the courts in 25 years, in the same comprehensive but centralized method of the board.

Patent litigation is a parasite on the development of the

art. Every patent attorney has to be assisted by a whole corps of experts, and I could cite you examples of several recent cases, apparently very simple, which in effect practically stopped the operations of several companies because their engineers were being used by the lawyers as experts.

This art is just coming to the point where it is to justify its inception as one of the blessings to mankind, and nothing should be allowed to interfere with the commercializing plan mapped out. It has proved its value from a military point of view during the war. It has had a great commercial value in the past, but its future is almost without limit, and should be realized, by subsidy, if necessary, rather than by placing useless stumblingblocks in its path.

I could easily make you a table showing how just one of the patents considered by the board could be the subject of seven or eight suits, with reasonable hope of substantial recovery, and when we take all the patents which would have the same reasonable hope of recovery, and show the combinations of suits which could be brought, it would easily reach the hundred mark.

The Chairman: Would it be very difficult to make that kind of a table?

Commander Loftin: No, sir.

The Chairman: The House wants to know about that. If you could take one of these claims and show just exactly what could be done under the patent law, and insert it in the hearing, I am sure the committee will appreciate it very much.

Commander Loftin: That matter is really very simple. For instance, we can take just one of the patents that the board has found to be good, and we can say that the Government has bought apparatus from at least eight contractors employing that particular patent. For that patentee to reach those contractors and get from them what the law allows him—their profits—he would have to file a suit against each one of them, in most cases in different jurisdictions.

The Chairman: If the United States court found that a patent was valid and rendered a decision in favor of the [fol. 2476] holder of the patent, would not the other contractors immediately confess judgment, because the opinion in the one case, affirmed, of course, by the higher courts, would be a precedent in the other cases?

Commander Loftin: That always has an influence on the fellow who is subsequently being sued; but in most of these cases the Government has saved the contractors harmless, so that we would really have to go out into the district courts and watch those suits and see that the contractor who was being sued did not throw up the case (he having been saved harmless by the Government), leaving a situation wherein he could come back to the Government and say, "Reimburse me; I have lost in this court on that particular contract," and the patent owner then having secured judgments in the district courts, could come to the Court of Claims and file a suit against the Government for the use of that apparatus. So that it easily runs up in some cases to 7, 8, 9, or 10 suits. If we take the 27 patents and multiply that number by 5, allowing a factor of safety on the number of suits being brought, that would easily total over a hundred suits.

The Chairman: That would make 135.

Commander Loftin: Yes. That table is not very difficult to make. I could name specific patents and specific apparatus which was involved, and specific contractors if it would be of any value to the committee.

The Chairman: We will appreciate it if you will kindly put that in the hearing.

Mr. Morin: The validity of these patents is not questioned, is it?

Commander Loftin: In this bill?

Mr. Morin: There is no question as to the validity of the patents?

Commander Loftin: On some of them we did question the validity and made no allowance on them, and our figures have been accepted by the claimants.

Mr. Morin: The allowance has been based on the use of the patents that have been found valid?

Commander Loftin: Yes; and the manufacture also. This whole settlement includes the contractors for the Government as well as the Government, the particular necessity for that being that the Government has agreed in many cases to save the contractor harmless. Now, under the act of 1918 we have the entire responsibility anyway.

Mr. Morin: You have not allowed any claims where the validity of the patent is in doubt?

Commander Loftin: No, sir; unless the doubt was such that it could reasonably be resolved in favor of the patentee.

I might say here that I am informed that the courts generally lean over backward to sustain a patent, but I do not think we have gone quite that far. We have required them to come somewhere near the middle ground before we have held that the patent is good. But the courts are very liberal with inventors and will generally resolve a very strong doubt in their favor.

The Chairman: The men who own patents think that the infringers have things all their own way. You may proceed with your statement.

Commander Loftin: The Government has largely held the contractors harmless, through war necessity, and would [fol. 2477] naturally have to defend all the suits to keep indifferent contractors from forfeiting them, and I believe this would mean new quarters for the Attorney General, with a patent department as large as his whole present organization.

In practice, then, this robs patent attorneys of a most promising, lucrative field of occupation for years to come, and saves untold expense in litigation, both to the Government and to patent owners. It practically frees the entire field of prospective litigation and allows the engineers of the companies to go about their legitimate business of improving and perfecting, rather than trying to save from the scrap heap what has been done before. It would practically ruin the Government organization, as radio experts are extremely few, and the Department of Justice would commandeer everyone for litigation.

The Chairman: Have you heard from the patent attorneys?

Commander Loftin: We have had many of them before us.

The Chairman: Are they in favor of this report?

Commander Loftin: Yes; they are quite reasonable about it.

It encourages an art for it to from time to time see that some compensation is being paid for the work being done. The Government has no too good reputation as to its relation to inventors, and yet this method does not encourage the undeserving, as every claim has been sifted down to its real merit.

This board has not aroused any hard feelings. Litigation always does. In our dual status of being court and defense,

we have had to keep open minds, and I believe we have won the confidence of every claimant who has been before us.

By our work the Government knows just where it stands in the radio-patent situation, and through this knowledge has been enabled to negotiate some very desirable patent arrangements for the future; yet all of this good work could be readily nullified if no settlement was had out of this board's efforts and the whole field thrown into litigation.

The Government stopped all litigation during the war by appeals both to litigants and courts. The board stopped it during its work in order to leave the situation in status quo, as it would have been impossible to deal with a situation constantly changing.

I have no knowledge of any substantial reward to any patent in this art. There have been many suits, but the operators heretofore have been financially weak and the judgments have not meant anything.

The Chairman: Did I understand you to say if they had secured judgments when you make this settlement those possible judgments will all be wiped out?

Commander Lottin: Yes, sir; as far as the Government apparatus is concerned. It does not mean that, as far as some commercial company is concerned, which has been operating commercially.

The Chairman: It is only the Government we are interested in.

Commander Lottin: We feel that the operations have been so small that if they settle with the Government it will stop the other suits and allow those men to go ahead in the matter of development. While great advance has been made, there are many problems to be solved, and all that can be done to help solve those problems is going to be of value.

[Vol. 2478.] It may be of particular interest to know that while the interallied communications conference was in session here in Washington last fall a number of representatives of the British Government at that conference, who were also radio men in Great Britain, learned that such a board was in progress here. They came to us and said they had quite a similar situation in Great Britain, and having learned of our board they would like to have the details as to procedure, what was proposed to do, and how far we had gone, etc., so that they might inform the British Govern-

ment of this form of procedure. After they returned home we learned informally that they had organized such a board in Great Britain.

The Chairman: That was subsequent to the time when they were here?

Commander Loftin: Yes, sir. We had our naval attaché in London inquire as to whether or not that was a fact, and we had a brief report saying that such a board had been organized, but with a personnel much more widely known than the personnel who compose this board.

The Chairman: That shows that they learn things from other countries.

Commander Loftin: They are using what we call in the Navy "deep draft" men—big men.

The Chairman: We can probably learn from other countries, too.

Commander Loftin: Such a board is in progress, and they intend to go further than merely the radio art and are going into other arts in an endeavor to settle numerous claims which have been brought.

The Chairman: Do you think that was the reason why they came to no agreement whatever in this matter of cable transmission—telegraphic transmission?

Commander Loftin: You mean while the conference was in session here?

The Chairman: Yes.

Commander Loftin: They came to many agreements on many points.

The Chairman: On the principal point they did not come to an agreement, or rather they determined to leave the matter to their ambassadors, and they have come to no conclusion yet.

Commander Loftin: They are to proceed again this summer.

The Chairman: And the next summer, and the summer after that, I imagine. You may proceed.

Commander Loftin: The claims which have been stated are \$14,800,000, by 7 out of 24 claimants. If all of them had stated an amount, it would probably have been thirty or forty million dollars.

We think it represents a good showing as to the accuracy of our work to pare these claims down to approximately

\$2,500,000 and still keep the claimants happy. They are all with us now; you will find them probably putting in a word for themselves, as they have an opportunity, and we certainly see no objection to that. They have worked hard with us and have met every request that the board has made, and we think it is only fair that they should have an opportunity to state their side of the case from time to time, as considered advisable.

The Chairman: Are the Deforest Co. and the other company which you named the only two that are out of this settlement now entirely?

[fol. 2479] Commander Loftin: No, sir; not entirely.

The Chairman: I think the committee would like to know, and it is desirable that we tell the Members upon the floor of the House, just how many claimants are willing to stand by this agreement.

Commander Loftin: I will go through the list of claimants and tell you just what we have done in each case.

In the case of the Vreeland Apparatus Co. we have not made any recommendation as to their claim.

The Chairman: Have you considered it?

Commander Loftin: We have considered their claim very fully, and their claim has also been considered in part—not all their patents—but two out of four of their patents were also considered by the Munitions Patents Board along with us, and their claim was rejected also by that board.

The Chairman: Was it rejected by your board?

Commander Loftin: Our board and the Munitions Patents Board, as far as they considered their claim, which included two out of four patents. We considered four patents, but two of them for special reasons went to the Munitions Patents Board also.

The Chairman: You have rejected it, so far as you are concerned?

Commander Loftin: Yes, sir; we have rejected it.

Mr. Parker: Might I ask you this question, and that is, whether you will settle if the Government used any of the machinery? If they sold the machinery, of course they can not charge for its use.

Commander Loftin: No, sir; they were not a manufacturing company.

Mr. Parker: But suppose the Government simply used the machinery?

Commander Loftin: They were a patent holding company. Now, take the case of the Marconi Wireless Telegraph Co. We reached a settlement with this company and will secure an absolute release from that company under their entire patent situation, which includes some three hundred and fifty and odd patents up to the time that company transferred its holdings to the Radio Corporation of America.

Mr. Wright: Would it not be well to have the amounts of the claims set out, Mr. Chairman, and also the amounts allowed?

Commander Loftin: Where the amounts have been stated we can do that.

The Chairman: Will it take a great length of time?

Commander Loftin: I have sent to you, Mr. Chairman, a draft of the preamble of our report to the several secretaries. That goes into the general phases of the board's work, including the proposed allowances to the several companies. That is not quite complete, but I see no objection to its going into the record, if you desire to have it printed.

Mr. Garrett: Does that include the list of the amounts claimed, and also the amounts allowed?

Commander Loftin: Yes, sir.

The Chairman: You have that in the report, a copy of which you sent to me?

Commander Loftin: Yes, sir.

Mr. Morin: Have you a list of the awards made?

Commander Loftin: Yes, sir.

[fol. 2480] Mr. Morin: It seems to me if that is included in your statement, it would be well to include the entire matter.

Commander Loftin: That is included in the statement which I sent to the chairman, and that will cover the whole matter, unless these amounts stated would bring out some points you would want to ask questions about.

Mr. Parker: Does your statement show whether the machinery was purchased, or whether you made your own machinery?

Commander Loftin: Practically all our apparatus has been made by commercial concerns. We have made a small amount in the Government navy yards.

Mr. Parker: Was any of it made by the patent companies themselves?

Commander Loftin: In a good many cases; yes.

The Chairman: That would all be shown in the statement which you have?

Commander Loftin: We have not shown in our statement which companies are manufacturing and which, apparently, are straightout patent holding concerns, or individuals, who have no facilities for manufacturing.

Mr. Parker: What I meant was, if these people furnished you the machinery and you bought it, you would be free from any royalties.

Commander Loftin: We have taken care of that; we have made no allowance where they have furnished the apparatus themselves.

The Chairman: If there is no objection, the report you refer to may be included in the hearing at this point.

(The report referred to is as follows:)

Report of the Interdepartmental Radio Board as to Claims  
Against the United States by Owners of Radio Patents

Washington, D. C., May 11, 1921.

The Secretary of War,

The Attorney General of the United States, and

The Secretary of the Navy.

This board is comprised of representatives appointed by the Secretary of War, the Attorney General, and the Secretary of the Navy, and constituted as follows:

Lieut. Commander Edward H. Loftin, United States Navy, president, and Commander Stanford C. Hooper, United States Navy, representing the Navy Department.

Robert H. Young, Esq., recorder, and Capt. Guy Hill, United States Army, representing the War Department.

Harry E. Knight, Esq., representing the Department of Justice.

(See "Precept," Paper A.)

### History

The steps leading up to the appointing of this board were the following:

Prior to the entry of the United States into the war a single suit involving radio patents had been brought in the

Court of Claims against the Government, namely, that of the Marconi Wireless Telegraph Co. of America against the United States, filed July 29, 1916. At this period the contracts of the Government, in general, including those relating to radio apparatus, required that the contractor should indemnify the Government from any loss arising out of claims for infringement made by reason of the infringing of the contractor's apparatus, and the responsibility of the Government was specifically stated by the act of June 25, 1910 (ch. 423, 36 U. S. Stats., 851).

In January and February, 1918, the Western Electric Co., prior to final decision by the Supreme Court in the Cramp [fol. 2481] and Simon cases below mentioned, had insisted, as to its contracts with the Government, that it (Western Electric Co.) be held harmless in any patent litigation. In one such contract, for example, relating to a radio apparatus designated as an audio frequency amplifier, the supply officer at the navy yard in New York was instructed to award the contract to the Western Electric Co., subject to the following condition:

"The apparatus mentioned herein being required without delay by the United States Government said apparatus is furnished in this emergency without investigation of outstanding patents, upon the condition (to which the United States, in placing its order, agrees) that the United States will save the Western Electric Co. (Inc.) harmless from all claims for infringement of patents on account of the apparatus so furnished, the Government assuming with the patentees direct all responsibility for said patent infringement."

On March 4, 1918, the United States Supreme Court, in the cases of William Cramp & Sons Ship & Engine Building Co. *v.* International Curtis Marine Turbine Co. (246 U. S., 28) and Marconi Wireless Telegraph Co. *v.* Simon (246 U. S., 46), having rendered the opinion that in certain cases contractors with the Government were not protected by the act of 1910 from independent liability, it was represented to the Government, and particularly to the War and Navy Departments, that contractors could no longer safely undertake the warranty against infringement. See in this connection the letter from Deforest Co., dated March 14, 1918. Similar letters were received from the National Electrical

Supply Co., the Wireless Improvement Co., Emil J. Simon, the Wireless Specialty Apparatus Co., Kilbourne & Clark Manufacturing Co., and the Sperry Gyroscope Co.

The contracts with the Western Electric Co., referred to in said letter, had been made prior to the rendering of the decisions in the Cramp and Simon cases, the Western Electric Co. having (as already stated) made their bids in certain cases only on condition that such warranty be given. At this time there had been called to the attention of the Government claims of various companies owning patents for radio apparatus, particular stress being laid upon claims arising under adjudicated patents of the Marconi Wireless Telegraph Co. of America, the International Radio Telegraph Co., and the Deforest Radio Telephone & Telegraph Co.

On March 29, 1918, the Acting Secretary of the Navy caused to be addressed to the Deforest Radio Telephone & Telegraph Co. a communication accepting certain responsibility on the part of the Government for the protection of contractors against patent claims and by direction of the Secretary, the Bureau of Supplies and Accounts, Navy Department, was, on April 3, 1918, notified that letters of similar purport to that sent to the Deforest Co. would be sent by the department from time to time to other contractors where it appeared that such action was necessary, in addition to those mentioned in the first indorsement of the Solicitor for the Navy Department on April 3, 1918.

The Secretary of War issued similar orders and the Secretary of the Navy did likewise in several additional instances.

In order to ascertain and define the obligations which were being assumed by the Government under these guaranties, conferences looking to the reaching of an amicable agreement were had with the several companies and particularly with the Marconi, Deforest, and International Cos.

On June 14, 1918, a conference was held between a representative of the War Department and the Marconi Co.

Negotiations also proceeded with the Deforest and International Cos., and the claims of other patentees which had arisen or might arise were brought to the attention of the War Department and Navy Department and litigation began or was threatened involving the Government directly or indirectly.

In order that the action of the War Department and the Navy Department in reference to claims made to them and the action of the Department of Justice in regard to the litigation pending or proposed might be coordinated, it was, on the 13th of July, 1918, proposed by the patent section of the Bureau of Aircraft Production to the Secretary of War that a letter be addressed to the Secretary of the Navy and the Attorney General proposing the appointment of a board representing the three departments to investigate and negotiate settlement; and favorable responses having been given and action taken thereon, the present board was constituted, and, after various changes in personnel, it is composed of the representatives above stated.

Among considerations influencing the constitution of a board to which might be submitted all claims under radio patents were the following:

It was considered that under the conditions established by the acts of 1910 and 1918 the Government would be involved in a multiplicity of suits under patents and that these would be different in character, depending upon the time at which the infringement complained of occurred and, in some cases, upon the question of whether the Government or the contractors with the Government were original or contributory infringers. The varying conditions of warranties affecting different contracts, some warranties being by the contractor and some by the Government, in so far as liability of patent infringement is concerned, introduced a serious complication. Under these warranty contracts the Government naturally became interested in suits pending anywhere in the United States involving alleged infringement of letters patent under which claims might be made against the Government.

These questions became particularly important in the radio art, which involves considerable difficulty in understanding its principles and in making them clear to any court not technically trained. The art is, furthermore, new and rapidly developing, so that the condition of patent protection is in a state of flux, and the entire field of accounting is embraced by still living patents. The number of claimants in this line and the patents involved were numerous, the contractors were also numerous, and the variation in forms of apparatus was and the conditions of the contracts were such that a claimant for compensation under a patent was in the position in some instances of being a warrantor

to the Government under all patents but his own. The great importance of the radio art to the conditions of modern war and the necessity for ignoring everything but efficiency and speed in securing equipment produced an amount of infringement upon radio patents in the last few years all out of proportion to what would have occurred in ordinary times.

A board comprising representatives of the several departments involved would consolidate the accounting into a single process which, in other event, might have had to have been repeatedly repeated for proceedings involving different departments of the Government, different patents and different jurisdictions. It would enable the coajoint consideration of the various claims and the various patents and thus protect the Government from having to pay multiple compensations for the same installation, for each patentee could be counted upon to urge in court the exclusive importance of his invention, and if each were granted compensation without the consideration of the claims of other patentees, the Government would undoubtedly be involved by successive suits in a total amount out of all proportion to what would be involved if all claims were presented to a single tribunal and each compelled to take his fair proportion of a total sum, for it must be admitted that the compensation due to a patent can not go beyond the value which the invention of that patent has added to pre-existing art, and that value is most safely measured by the profit that can be made upon the improved machine, whether by the patentee or by the purchaser as compared with what can be made with prior machines. This sum, being determined either accurately or roughly as the circumstances of the case admit, must be allocated to all patented inventions contained in the machine and properly between them with some attempt of relative valuation and after deduction, also accurately or roughly as the case permits, of the share that is due to old or unpatented parts of the machine.

The saving by such a proceeding of delays and expenses of numerous litigations in numerous courts is obvious, and it may be assumed that if the Government by such a proceeding can ascertain the amount acceptable to claimants and substantially equivalent to what they could expect by continuance of litigation, the Government will have been fully justified by reason of the saving of the time of its personnel and the expenses involved in litigation.

The Interdepartmental Radio Board thus constituted held its initial meeting and organized on August 16, 1918, and began the preparation of a complete detailed statement of the radio apparatus which had been bought, constructed, and used by the War and Navy Departments, segregating the apparatus as much as possible with relation to the patent art as it has progressed.

Prior to the signing of the armistice in November, 1918, the operation of the board was interfered with by the detailing of its members in war operations. On February 12, 1919, a letter was addressed to each of a list of patent owners.

The Wireless Improvement Co., J. S. Stone, Cutting & Washington, and Cooper Hewitt Electrical Co. submitted no claim. The following parties responded that they had no claims to be satisfied or negotiated: Federal Telegraph Co., General Radio Co., Liberty Electric Corporation, Moorhead Laboratories (Inc.), American Radio & Research Corporation, Westinghouse Electric & Manufacturing Co., Kilbourne & Clark Manufacturing Co.

[fol. 2483] Claims for compensation were made by the following:

1. Vreeland Apparatus Co.
2. Marconi Wireless Telegraph Co.
3. International Radio Telegraph Co.
4. DeForest Telephone & Telegraph Co.
5. Louis Cohen.
6. E. H. Armstrong.
7. Emil J. Simon.
8. Sperry Gyroscope Co.
9. American Telephone & Telegraph Co.
10. Reginald Fessenden.
11. Clapp-Eastham Co.
12. Wireless Specialty Apparatus Co.
13. Lowenstein Radio Co. (Inc.).
14. Dubilier Condenser Co.

The following claims were added later:

15. General Transmission Co.
16. John Firth.
17. H. M. Horton.
18. National Electrical Supply Co.

19. Joseph Raes.
20. Title Insurance & Trust Co.
21. Peter E. Stogoff.
22. J. Harris Rogers and H. H. Lyon.
23. J. Harris Rogers.
24. American Mechanical Improvement Co.

An additional circular letter, inquiring as to the condition of cross licenses affecting the patents involved, was sent May 15, 1919, to the several claimants.

The answers to this second circular letter were before the board when the individual claims were considered.

The board thereupon proceeded to consider the several hundred patents set forth in these claims, and on September 25, 1919, had progressed so far with this examination that a letter was sent to the several claimants appointing hearings.

Later notices were sent to the remaining claimants and in due course the claimants all appeared before the board and hearing was had orally in each case. During the discussion of the claims with the various claimants, numerous patents were eliminated by withdrawal of claims thereon, so that there were left for consideration by the board claims based only on the following:

	Number of Patents
1. Vreeland Apparatus Co.	4
2. Marconi Wireless Telegraph Co.	4
3. International Radio Telegraph Co.	29
4. DeForest Radio Telephone & Telegraph Co.	62
5. Louis Cohen	1
6. E. H. Armstrong	1
7. Emil J. Simon	1
8. Sperry Gyroscope Co.	2
9. American Telephone & Telegraph Co.	70
10. R. A. Fessenden (not formally presented).	
11. Clapp Eastham Co.	1
12. Wireless Specialty Apparatus Co.	12
13. Lowenstein Radio Co. (Inc.)	2
14. Dubilier Condenser Co.	4
15. General Transmission Co.	1
16. John Firth	1
17. H. M. Horton	1

	Number of Patents
18. National Electrical Supply Co.	2
19. Joseph Raes	1
20. Title Insurance & Trust Co.	1
21. Peter E. Stogoff	1
22. J. Harris Rogers and H. H. Lyon	2
23. J. Harris Rogers	5
24. American Mechanical Improvement Co.	1

This board has not in its consideration of the various claims that have been brought before it assumed to exercise a judicial function. It has had in view its position as a [fol. 2484] governmental agency, acting on the part of the Government, for ascertaining such reasonable compensation as may be allowed to the various claimants on a basis of settlement without suit, and in each of the conclusions it has reached upon controversial points it has given proper weight to the consideration that both the Government and the claimants will by acceptance of the board's conclusions avoid the expense, delays, and uncertainties of such litigation, and any conclusions which it may reach favorable to any claimant are not to be considered as binding upon the Government, nor as an expression of the Government's or of the board's conclusions on any of these controversial points, in the event that the action of the board does not lead to a final settlement without further litigation.

It also has been had in mind by the board that settlement for the amounts determined to be due the several claimants is to dispose of all claims of infringement arising out of the purchase, use, and sale of patented apparatus and methods, whether against the Government or against contractors with the Government.

The figures arrived at necessarily have been merely approximate. In some cases figures have been estimated from data in hand. In others, on account of lack of specifications or inaccessibility of apparatus for examination, the board has had to reach a conclusion based on verbal reports of officers.


The ascertainment of reasonable compensation has involved various difficulties.

Difficulty is found in determining the period of life and usefulness of individual instruments, and it is not known

and can not readily be ascertained in individual instances how long the period of usefulness is. It is difficult, therefore, to say whether an instrumentality purchased in 1914 may have gone out of use by 1915, at which time it may be there first issued a patent which covers it. It also is difficult of ascertainment whether the article purchased in 1914 was actually put in use in that year or was not actually put in use until 1917, or was ever put in use. This problem can be satisfactorily solved only by awarding the compensation upon the purchase of the article independently of the time and actuality of use, and this method has, in the main, been followed.

It has been ascertained by the board that while a proportion of the cost which might be allotted for compensation by way of royalty can be determined in individual instances of orders of specific instruments, in a large proportion of cases the relative cost of that instrument is not accurately ascertainable where it is incorporated in complete sets or parts of sets.

The board in arriving at a determination of the proper weight of the several patents, infringement of which has been declared, and of the value thereof in affecting reasonable compensation to the claimant, has had, in the first place, to consider whether the specific invention was general in character in so far as its use affected the value of the operation of the entire system or was so local that it involved merely the substitution in one part of the system of a device having for its reason for selection a mere improvement in convenience, cheapness, or other characteristic not involving a modification in operation of the system regarded as a whole. While an improvement might seem, so far as its claims are concerned, to be limited to the specific arrangement of certain elements in the entire wireless installation, where the result of this combination has been so important in affecting the successful operation of the entire system that an adequate return to the inventor would not be secured by awarding to him the proportion of the cost of that specific part of the apparatus, recognition is given by the board to this fact in determining that in such cases the royalty to be allotted to the claimant is to be as widely distributed in the apparatus as is the result of his improvement, or where the improvement is local the allotment of the royalty is equally localized.

  
2

In determining the proper amount of royalty in these two cases the board has had recourse to the several decisions of the Court of Claims in determining on what had been considered in individual cases the fair amount of royalty, and has also had in view the practice in commercial establishments in fixing a fair amount of royalty in individual cases, recognizing that the determination of a specific royalty in any individual case is largely an empirical matter and that the conclusions herein represent only a consensus of the opinion of the members of the board derived from the circumstances affecting each individual case.

Copies of all patents and publications referred to are made a part of the files of the board, being too numerous to be made a part of this report.

[fol. 2485] A list of prior litigations on radio patents, approximately complete, is found in paper No. 11.

A list of cases pending against the United States on radio patents in the Court of Claims is found in paper No. 12.

The claim in which amount claimed has been stated are as follows:

Marconi Wireless Telegraph Co. of America	\$6,000,000
DeForest Radio Telephone & Telegraph Co	2,000,000
Dubilier Condenser Co	60,000
Emil J. Simon	100,000
John Firth	50,000
Wireless Specialty Apparatus Co	6,500,000
Title Insurance & Trust Co	150,000
Total	14,860,000

The following claimants, while not expressing the definite sum of their claim, demanded a monetary award:

Vreeland Apparatus Co.  
 International Radio Telegraph Co.  
 Louis Cohen.  
 Edwin H. Armstrong.  
 Sperry Gyroscope Co.  
 Lowenstein Radio Co.  
 General Transmission Co.  
 H. M. Horton.  
 National Electrical Supply Co.  
 Joseph Raes.  
 American Telephone & Telegraph Co.

R. A. Fessenden (not proceeded with).

Clapp Eastham Co.

Peter E. Stogoff.

Dubilier Condenser Co. (on one patent not included in suit in Court of Claims).

J. Harris Rogers & H. H. Lyon.

J. Harris Rogers.

American Mechanical Improvements Co.

As the total purchases and manufacture of radio apparatus, during the period covered by the accounting—as will appear later in this report in discussing the accountants' figures—amounted to \$40,425,404.36, the total claims, considering the figures mentioned in discussion by the claimants not presenting definite figures, represented fully 50 per cent of the total cost of apparatus.

The various patents involved will be found more particularly identified in connection with each of the following reports. In the case of each claimant the various patents have been carefully examined with the aid derived from briefs or oral arguments submitted, and the board has, where necessary, examined the history of the patent as disclosed by the Patent Office record and reports of litigation, and has made as extensive a search of the prior art as has seemed necessary in each case. It has also made an extensive inquiry into the radio apparatus purchased or manufactured by the Government, examining the various apparatus where necessary and securing information as to actual details of their construction and operation from Government employees best acquainted therewith.

### Résumé

The following claims are denied by the board:

Marconi Wireless Telegraph Co., reissue patent 11913, coherer as receiving device.

International Radio Telegraph Co.:

742780, 752895, 1074423, 1002049, 1059666, 1156677,

1184843, interference preventers.

727331, reissue 12115, electrolytic detector.

706,745, receiver arrangements, stiff circuits.

730753, charging aërials from direct current source without interruption.

- 979144, 1020032, 1101914, 1101915, horizontal antennae of small elevation.  
 1050728, absorbing circuit, claim 9 of patent.  
 [fol. 2486] Wireless Specialty Apparatus Co.:  
 1118228, noncopper compounds.  
 876996, loop antenna.  
 1213250, detector circuit.  
 893811, Leyden jar.  
 1127921, tap tuner with micrometer variation.  
 904222, chemical compounds.  
 1104065, cat whisker (nonuse).  
 1104073, cat whisker.  
 National Electrical Supply Co., design patent 48638, hand generator.  
 Joseph Raes, 1099861, portable tower for radio field station.  
 Vreeland Apparatus Co.:  
 829447, 829938, oscillion circuit.  
 1245166, combination of continuous wave transmitter with signals controlled by change of frequency and a heterodyne receiver.  
 1239852, heterodyne receiver.  
 Dubilier Condenser Co., 1279850, buzzer transmitters.  
 General Transmission Co., 1216615, quenched cap circuit.  
 Title Insurance & Trust Co., 1315197, low frequency system.  
 Peter E. Stogoff, 1343165, submarine radio system.  
 J. Harris Rogers and H. H. Lyon, 1220005, 1322622, buried-wire antennae.  
 J. Harris Rogers:  
 1315862, underwater antenna coil.  
 1316188, loop antenna.  
 1303750, 1349103, 1349104, specific forms of buried-wire antennae.

The following claims have been settled or withdrawn:  
 American Telephone & Telegraph Co., Clapp-Eastham Co.,  
 De Forest Radio Telephone & Telegraph Co., Dubilier Con-  
 denser Co. (mica condenser patents).

The board recommends that an offer of settlement be made to the following claimants:

The Marconi Wireless Telegraph Co. of America, under letters patent of Lodge No. 609154, Fleming 803684, and the Marconi patent 763772.

The International Radio Telegraph Co. (National Electric Signaling Co.), under patents of Fessenden, Nos. 706742, reissue 12168, 706746, 706747, 727830, 753863, 1050441, and 1050728. (No instances of infringement have been found upon this claimant's patents 846081, 950781, 1158112, and 1182946.)

Dr. Louis Cohen on his patent 1123098.

Emil J. Simon on his patent 1253103.

Lowenstein Radio Co. upon its patents 1258423 and 1305816.

E. H. Armstrong on his patent 1113149.

John Firth on his patent 1018769.

National Electrical Supply Co. on its patent 1145066.

Sperry Gyroscope Co. on its patents 1287116 and 1362753.

H. M. Horton on his patents 1165412.

American Mechanical Improvement Co. on its patent 1238838.

Wireless Specialty Apparatus Co. on its patents 836531, 912613, 933263, and reissue 13798.

Settlements having been made with the American Telephone & Telegraph Co. and the Dubilier Condenser Co., no recommendation is made as to these claimants. R. A. Fessenden having failed to formally present his claim, no recommendation is made as to it.

Considering that the value of the respective inventions to the Government can not be ascertained from returns from commercial uses of the inventions, the Government's use having been largely noncommercial; that great difficulty exists in ascertaining whether in an individual case an apparatus has been put to use; that great divergence occurred in methods of purchase of apparatus; and that other circumstances lead to indefiniteness of any other method of approaching the problem of ascertaining the exact figures, it has been concluded that 15 per cent on the cost price comes as near to being a fair and accurate figure on which to base the board's calculations as can be reached. In applying this percentage it has not always been possible to ascertain what proportion of the cost price is directly assignable to radio apparatus per se, and the board has in doubtful cases often leaned in favor of allowance to the claimant where the records obtainable have not enabled it to segregate such items. In some cases the utmost investigation has not enabled the board to ascertain the exact construction of

apparatus and the board has had to proceed in such matters more or less by inference from surrounding circumstances. [fol. 2487] Note is taken in the accounting of the different terms of expiration of the several patents, of the diminutions in royalty due to the articles having been furnished by the claimant or its licensee, and an average period of three months has been allowed between the date of requisition of apparatus and their delivery in considering whether such apparatus comes within the terms of the accounting. The fixing of a reasonable compensation at 15 per cent where the patents involved have been fundamental has called for a lesser allowance under the authority of the *Westinghouse*, *Dowegiac*, and other cases,<sup>1</sup> where other elements enter in limiting the proportion, as, for example, the expiration of one or more of the fundamental patents, its conclusion in the cost price by reason of the article having been furnished by the patentee, or the necessity of apportioning a compensation between a number of claimants. In the case of apportionment of a total royalty regard has been had to the relative importance of the invention in the individual cases. Where the invention is not fundamental but has referred to an individual part or piece of apparatus used as an improvement on or substitution for a previously used device, a basis of compensation at the rate of 10 per cent has been allowed, with suitable apportionment, where several patents are concerned in the article; and in certain cases of minor importance the compensation has been limited to a less percentage. The board has not pretended to reach mathematical exactitude, nor does it consider this necessary. (*Underwood Co. v. Stearns & Co.*, 227 Fed., 74.)

In subdividing the subjects matter of radio apparatus purchased it has been convenient to take them up under the following heads:

- |                          |                        |
|--------------------------|------------------------|
| 1. Complete transmitters | 4. Detectors (crystal) |
| and receivers.           | 5. Arc transmitters.   |
| 2. Receivers.            | 6. Receiving tuners.   |
| 3. Transmitters.         | 7. Vacuum tubes.       |

<sup>1</sup> See *Garretson v. Clark* (111 U. S., 120); *Westinghouse v. Wagner* (225 U. S., 604); *Dowegiac Manufacturing Co. v. Minnesota Co.* (235 U. S., 641); *Dehoning v. Fox Type-writer Co.* (251 Fed., 584).

- |                                  |                       |
|----------------------------------|-----------------------|
| 8. Wave changers.                | 13. Audion detectors. |
| 9. Wave meters.                  | 14. Condensers.       |
| 10. Decimeters.                  | 15. Radio telephones. |
| 11. Quenched gaps.               | 16. Amplifiers.       |
| 12. Direction-finding apparatus. |                       |

As a rule no deductions have been made for patents owned by the Government or patents or inventions not before the board as claims. Departure from the rule has been made, however, in the case of the quenching-gap inventions. These inventions are of such importance in their relation to quenched-gap transmitters that it has not been thought reasonable to exclude them because several patents covering this feature came into the possession of the Government during the later part of the period of the accounting.

Another exception has been made in the case of the Poulson arc patents for similar reasons.

*Complete transmitters and receivers.*—The transmitters of these sets have been (1) with open-gap excitation, either fixed or rotary; (2) with quenched gap excitation; (3) with pure impulse excitation; (4) vacuum-tube excitation. (Are transmitters and alternator transmitters are separately considered.)

The receivers of these sets have as a rule had two tuned circuits. Reference to the accounting sheets will indicate that each separate item constituting an order has been separately estimated with dissociation of the costs of the transmitter and receiver and with application of the several patents, first, to the transmitter; and second, to the receiver cost.

(1) *Open-gap transmitters.*—The foundation patents involved have been Lodge, Marconi, and Stone,<sup>2</sup> the basis being 15 per cent, 5 per cent each.

(2) *Quenched gap transmitters.*—The foundation patents involved are Lodge, for loading coil and impulse excitation; Marconi, for tuning and the quenching gap inventions, the basis being 10 per cent for the Marconi Co. patents and 5

<sup>2</sup> Loose coupling is for convenience identified with Stone's name, although no award is made here to owners of those patents.

per cent for quenching gap inventions. Specific allowances deducted from these sums, however, have been made for the Simon individual quenched gaps. (No Lowenstein type gaps are found in these sets.)

(3) *Pure impulse excitation*.—All patents before the board involved in this form of transmitter had expired before any purchases were made.

[fol. 2488] (4) *Vacuum-tube excitation*.—Only a few sets of this kind were found under this heading, and the compensation was distributed among the Fleming valve patent, the DeForest tube patents, the heterodyne patent, and the Lodge patent, the rates varying according to the uses to which the sets were put.

*Receivers of complete transmitters and receivers*.—The basis of arrangement is shown more fully when orders comprising receivers alone are reached, the only difference in this case being that the cost of receivers of these sets have been estimated where no information was available as to the cost of the receiver *per se*.

*Receivers*.—These are divided into three heads:

(1) Receivers arranged with terminals for any form of detector.

(2) Receivers having built-up accommodations for vacuum tubes (*a*) arranged for both oscillations and regeneration, or (*b*) arranged for oscillations only.

(3) Radio compass receivers.

(1) *Receivers arranged with terminals for any form of detector*.—The foundation patents are Lodge, Marconi, and Stone. Where the Lodge and Marconi patents are involved the full 15 per cent has been allowed to Marconi, diminished by 5 per cent for the Stone loose coupling patents when they were in question and diminished by a further 5 per cent on the expiration of the Lodge patent. Where mountings for crystal detectors were included, an amount of \$1 per mounting has been deducted for the Wireless Specialty Apparatus Co.

In a few instances of statically coupled receivers of the Cohen type, an allowance was made the Cohen static coupling patent at the rate of 3.75 per cent. It has not been overlooked by the board in reaching this figure that a larger amount has in some instances been paid to Mr. Cohen by contractors—an amount based, in part at least, on en-

gineering services. A proper apportionment of credit has resulted in fixing the above percentage, and credit has been made in these few instances without disturbing allowances already made on these sets to other patentees.

(2) *Receivers having built-in accommodations for vacuum tubes.*—(a) Arranged both for oscillations and regeneration: The inventions involved were Lodge, Fleming, Marconi, DeForest tube and Stone loose coupling, the Armstrong regenerating circuit and the heterodyne, and allowance made (Lodge having expired) at the rate of 5 per cent for Marconi and  $2\frac{1}{2}$  per cent for each of the remaining claimants.

(b) Arranged for oscillations only: The patents involved are Fleming, Marconi, DeForest, Stone, and heterodyne. On account of the relative importance of the heterodyne invention in these sets, the allowance has been at the rate of 4 per cent for Marconi and Fleming patents, 4 per cent for the DeForest and Stone patents, and 4 per cent for the heterodyne patents.

These are the main subdivisions. Still other somewhat different forms are found in which some variation has been made, depending upon the arrangement of the structure and the use to which it is put.

*Transmitters.* There are (1) spark transmitters (open gap); (2) quenched gap transmitters; (3) vacuum-tube transmitters; (4) buzzer transmitters. The apportionments of royalties are the same as in transmitters of complete transmitters and receivers.

*Detectors (crystals).*—Allowance for the crystals themselves and their mountings has been made at the cost or estimated cost price thereof at the rate of 10 per cent to the Wireless Specialty Apparatus Co., where their patents were involved.

*Arc transmitters.*—These have included stations in which long waves were employed and those in which short waves were employed, and the patents involved are the Fessenden long wave, the Fessenden inductance shunt key, the Fessenden heterodyne patents, the Lodge patent, and the Poulsen arc patent, with an allowance of  $7\frac{1}{2}$  per cent, as a rule, to the International Radio Telegraph Co.,  $2\frac{1}{2}$  per cent to Marconi Co., and 5 per cent to the Poulsen patent. In cases omitting the inductance shunt key the allowance to

the International Radio Telegraph Co. has been reduced to 5 per cent. In the case of the New Brunswick station allowance was made at the rate of 10 per cent to the International Radio Telegraph Co., based on the amount paid for the maintenance of the station during the Government occupancy. No allowance has been made for the Tuckerton Station, this matter being in litigation.

In the accounting no reference is made to the Bordeaux (Lafayette) Station, erected by the Government on French soil, with radio material furnished from this country, under the doctrine of *Bullock v. Westinghouse* (63 C. C. A., 607). Furthermore, this station was not completed during the time of this accounting.

[fol. 2489] *Vacuum tubes*.—The equal rate of 5 per cent has been allowed to the Fleming valve and the DeForest patents, following the rule which was generally adopted of allowing a total compensation of 10 per cent where the patents related to an individual part of the apparatus rather than to the whole system.

*Wave changers*.—The only patents involved are the Lodge and Marconi patents, and the allowance varied from 5 to 15 per cent, depending upon the use of quenched gap and the period of purchase. The device itself is not an infringement, but allowance has been made on the assumption that these wave changers were purchased for incorporation in sets involving one or both of these patents.

*Wave meters*.—Allowance has been made at the rate of 10 per cent of the cost of detectors for the Wireless Specialty Apparatus Co. and 10 per cent of the cost of the condensers for the Lowenstein Co. (where the condenser is logarithmic type) and at the rate of 5 per cent of the total in the case of special wave meters involving the heterodyne patents. On the special uni-polar detectors of the Midgely type an allowance of  $7\frac{1}{2}$  per cent has been made to the Midgely patent.

*Decremeters*.—An allowance of 10 per cent of the cost of the condensers per se of a decrometer has been made for Lowenstein's logarithmic condenser patent.

*Quenched gaps*.—These have been bought as replacements of other gaps, and it is not considered that compensation on the system patents should be allowed. Where the Simon gap has been used allowance has as a rule been made to Simon at the rate of \$10 less depreciation where the purchase has occurred before the date of his patent, but where

the individual units have been purchased the allowance has been at the rate of 5 per cent of the cost. In one instance in which the set was furnished with the Lowenstein switch allowance has been made to Lowenstein at the rate of \$10 per set less depreciation for purchase prior to grant of his patent. Such gaps have averaged \$200 each purchase price.

*Direction finding device.*—Where the patents involved were Fleming, Deforest, Armstrong, and heterodyne,  $3\frac{3}{4}$  per cent has been allowed to each claimant.

*Audion detector and Audion control boxes.*—Allowance of 5 per cent has been made to Marconi for the Fleming patent and 5 per cent to the Deforest patents, except in one instance in which tickler coils were used, when the allowance has been at the rate of  $3\frac{3}{4}$  per cent to Marconi for the Fleming patent,  $3\frac{3}{4}$  per cent to Armstrong,  $3\frac{3}{4}$  per cent to the heterodyne patent, and  $3\frac{3}{4}$  per cent to the Deforest patents.

*Condensers.*—An allowance to Lowenstein is made in the instances in which his logarithmic condenser invention is employed at the rate of 10 per cent less depreciation prior to the grant of his patent.

*Radio telephones.*—The patents involved were Fleming, both transmitter and receiver as a rule, the Fessenden telephone patents, the Armstrong regenerating circuit, and the Deforest patents. The allowances have varied according to the importance of the patents to the set, being in the main at the rate of 6 per cent to Marconi, 3 per cent to the International Radio Telegraph Co., and 3 per cent for the Deforest patents at the receiver, and  $3\frac{3}{4}$  per cent to each of these claimants at the transmitter, the allowance to Armstrong varying from 2 to  $2\frac{1}{2}$  per cent where his invention was involved, with corresponding reduction of the other allowances in these cases.

*Amplifiers.*—The allowance has been at the rate of 5 per cent for the Fleming patent and 5 per cent for the Deforest patents, no allowance, however, having been made for the Fleming patent for vacuum tube amplifiers constructed for purely low frequency or "TPS" conductive signaling.

*Receiving tuners-variometers.*—Allowance is made to the Marconi Co. at the rate of 5 per cent for the Marconi tuning patent.

*Heterodyne method.*—The allowance for primary radio stations is fixed to average \$2,000 per station, and for

secondary radio stations \$500 per station under the heterodyne method patent of the International Co.

*Arco fans.*—An allowance of 10 per cent has been given where such fans fall within the terms of Slate patent 1,238,838. The Sperry patents have been made the subject of a special recommendation for a part and future license for a fixed sum.

*Airplane radio.*—The Horton patent has been made the subject of a special recommendation for a past and future license for a fixed sum.

[fol. 2490] The complete list of apparatus taken from Government records by the accountants is shown in the sheets filed among the board's records and not attached to this report. Tables estimating the compensation due the several claimants as estimated by the board on each order are annexed thereto.

The total amount due from the Government to patent owners is found by the board to be \$2,869,700.27, apportioned as follows: By the Army, \$1,050,179.58; by the Navy, \$1,819,520.69; total, \$2,869,700.27, and divided among the claimants as follows:

Marconi Wireless Telegraph Co. of America	\$1,253,389.02
Wireless Specialty Apparatus Co.	322,449.69
American Telephone & Telegraph Co.	615,333.57
Sperry Gyroscope Co.	5,000.00
E. H. Armstrong	89,624.74
E. J. Simon	30,273.31
International Radio Telegraph Co.	711,451.85
H. M. Horton	75,000.00
Lowenstein Radio Co.	22,892.80
National Electrical Supply Co.	8,875.00
Dubilier Condenser Co.	18,194.31
American Mechanical Improvement Co.	383.80
Louis Cohen	1,271.25
John Firth	15,560.93

The claims of the American Telephone & Telegraph Co. and the Dubilier Condenser Co., so far as included in the above amounts, have been waived or released to the Government under agreements between the claimant and the United States recently consummated, leaving as the net

<sup>2</sup> Determination not yet final.

amount of the total of the claims considered valid and outstanding \$2,236,172.39, of which the Army's pro rata is \$658,871.11 and the Navy's pro rata is \$1,577,301.28.

### Precept

#### [Paper A]

Whereas the operations of the War Department and the Navy Department during the war relating to the furnishing of adequate supplies for radio communication developed the fact that the patent rights of greatly needed supplies were diversely held, which rendered quantity production by the employment of all of the available manufacturing facilities difficult, which situation made obvious the necessity for proceeding with production without regard to the existence of patent rights, orders for which procedure were issued by both departments, wherein the United States Government directly assumed responsibility for the proper compensation for the unauthorized use of patent rights; and

Whereas large claims were presented to the United States, flowing out of such procedure, in addition to others which already had accumulated and for which suits had been filed against the United States in the Court of Claims; and

Whereas the situation thus produced made obvious the advisability of creating a board of experts in patent law and radio science for the purpose of determining scientifically the measure of liability in which the Government became involved; and

Whereas the Secretary of War suggested the creation of such a board to the Secretary of the Navy and the Attorney General, in which suggestion they concurred and out of which was created by separate appointment representatives of the Secretary of War, the Secretary of the Navy, and the Attorney General, to constitute the Interdepartmental Radio Board, which board has been heretofore organized and has made considerable progress in the discharge of the duties the problem presented seemed to require.

Now, therefore, it is directed that the officers and representatives of the several departments heretofore appointed, to wit, Commander Stanford C. Hooper, United States

Navy, and Lieut. Commander Edward H. Loftin, United States Navy, representing the Navy Department; Capt. Guy Hill, United States Army, and Robert H. Young, Esq., representing the War Department; Harry E. Knight, Esq., representing the Department of Justice; and any successors [fol. 2491] of any of said members who shall hereafter be, from time to time, appointed shall continue as a board, designated the Interdepartmental Radio Board, to investigate, hear, and examine the questions relating to the liability involved in the use by the Government of patents on radio apparatus and similar devices and render to the several heads of the departments mentioned their conclusions and recommendations therein.

Such assistance and information as the board may require will be rendered to it by the officers of the respective departments familiar with patent and technical matters involved in those departments.

Newton D. Baker, *Secretary of War*. Josephus Daniels, *Secretary of the Navy*. A. Mitchell Palmer, *Attorney General*.

To the Interdepartmental Radio Board,

*Navy Building, Washington, D. C.*

Washington, D. C., *February 12, 1921.*

Mr. Garrett: What do you mean by a patent-holding concern? Is that a concern which simply holds the patent rights and does nothing else, and is seeking to get certain awards?

Commander Loftin: It is a straight out exploiting of patents—selling licenses for patents.

Mr. Garrett: And the only investment they have is the patent itself?

Commander Loftin: We have not many of those to deal with; but sometimes capital will financially back an inventor, and it takes money to do that. They equip laboratories and sometimes arrive at something that is valuable.

Mr. Garrett: What you mean by a patent-holding concern is one that includes the original patentee with his financial backers—that is, he usually takes in a lot of people with him and they finance his project? Usually an inventor is a rather poor fellow and has not much money, and he gets some people to go in with him, and they put the patent on the market.

Commander Loftin: The Vreeland Apparatus Co. is the only company of that kind that we have a claim from. They may make a small amount of apparatus, but they do not make any radio apparatus. We have a number of individuals, of course, who have made inventions themselves.

Mr. Wright: Under the war power the Navy Department had the right to use any of these patents, even without the consent of the patentee?

Commander Loftin: Without the war power we have always had it, and it was not until the passage of the act of 1910 that we have had to pay for those things.

Mr. Wright: It is because of the use of these patents that these claims have been made?

Commander Loftin: Yes, sir.

Mr. Garrett: You say prior to 1910 the Government did not have to pay for them?

Commander Loftin: No, sir; the inventor had no way of reaching the Government, up to 1910, for the use of his invention. The act of 1910 gave him the right to make a claim in the Court of Claims, and the act of 1918 modified that act so that the Government takes all the liability; the [fol. 2492] contractor does not take any liability, as I understand the act, so that from now on we have to watch our step and take care of inventors.

Mr. Wright: You mean that up to the time of the war the Government could use any patent without the consent of the patentee?

Commander Loftin: That simply means the patentee can not enjoin the Government from using it.

Mr. Wright: You have compensated him?

Commander Loftin: We have recommended compensation where we have done that.

Mr. Garrett: Before that the Government exercised its function as a sovereign and did not concede that, having granted a patent to one of its citizens, the citizen possessed a greater right than the Government possessed when it wanted to use a patent for its own purposes?

Commander Loftin: There has been no provision made for it. The only way an inventor could make any claim at all was where the Government in some way implied or made a contract.

The Chairman: Is there anything further you desire to present to the committee?

Commander Loftin: There is one other point I would like to make as to the practical effect of what this board has been doing. We supplied thousands of ships of the Shipping Board with radio apparatus. The Shipping Board does not know that a patent situation exists in radio apparatus. They have had one or two letters from people who did not know that this board was functioning. So through this board we have allowed the Shipping Board to go ahead undisturbed in this complicated field of patents without knowledge of or interference from patent owners. They have all been coming to us.

If there had not been such a board as this, the Shipping Board would have been swamped with claims from the different patentees. I think they would have gotten to a point where they would have been glad to have thrown the apparatus overboard rather than to have used it under the annoyances they would have had if we had not been handling the situation for them.

I have recently had occasion to talk to some of those people about this general situation, and they thoroughly appreciate what has been accomplished for them. They know there is such a situation, but they have never felt its full purport.

Another point as to the seriousness of this proposition. Admiral Griffin, who is the chief of the Bureau of Engineering of the Navy Department, was greatly disturbed about this situation all through 1918, in the middle of the war, and I was in France at that time very much occupied in the development of the high-power radio system we were arranging for in case the cables were cut and we should be denied communication by that means.

It was very important work, and there were many details to be arranged with the British and French as to a real working communication system to take the place of the cables.

I was one of the few officers who had the advantage of having had a postgraduate course in this particular art, and Admiral Griffin desired that I should come back and take up this patent situation, and he made many urgent requests prior to the signing of the armistice for my release from [fol. 2493] the other side, but that was not approved by Admiral Sims on the other side because of the urgency of that work until after the signing of the armistice. I merely mention that to show that a man as busy as Admiral Griffin

was during the war had this on his mind, deeply imbedded in his mind, to the extent of trying to interfere with Admiral Sims's organization on the other side at a very crucial moment.

Mr. Parker: You say some of these patents, what they call pioneer patents—some patents are merely subsidiary patents; is that not so? I mean that the pioneer patent for radio communication was claimed by Marconi, was it not?

Commander Loftin: Yes, sir; we had that one before us.

Mr. Parker: Were there any conflicting claims for the basic patent between the DeForest and the Marconi Cos.?

Commander Loftin: No, sir.

Mr. Parker: I remember at the beginning of the war there was a great deal of trouble because the DeForest Co. wanted to stop our use of radio altogether.

Commander Loftin: The Marconi Co. has sued the DeForest Co. two or three times for use of the early Marconi patent and the second Marconi patent, which is well known in the art, and several others.

Mr. Parker: I am glad to hear that the DeForest Co. does not claim the basic patent, as against Marconi.

Commander Loftin: Not as to a wireless system. DeForest made a very important invention in what is known as an amplifier, the little vacuum tube which they use with the receivers, which has proved of such great value in intensifying the weak signals, allowing a certain amount of power to reach a much greater distance because of the greater strength at the receiving end.

Mr. Parker: I wanted to get at this—whether the DeForest claims were such that if the Marconi claims were allowed, the Marconi Co. would guarantee us against the DeForest claims. You say they claim different things?

Commander Loftin: They have had a claim on this particular tube. Both of them have very important patents in that particular tube, but they have no conflicting claims on a wireless system.

Mr. Parker: Have they conflicting claims on this vacuum tube?

Commander Loftin: They do not conflict; they are specific inventions which are easily separated.

Mr. Parker: Do they claim that either one infringes the other?

Commander Loftin: The Marconi Co. claims that the patent on the tube which involves the DeForest invention

infringes the patent which they own, and the courts have so held.

Mr. Parker: In that particular case, as to that particular article, ought we not to receive from the Marconi Co. as a part of their settlement, a guaranty against claims of the other company on that device?

Commander Loftin: It so happens in connection with that particular device that during the period when Deforest had a claim, without any legal question, he made all those devices. The Marconi Co. has a claim for those devices, but Deforest has not; he having furnished them, he has no claim, but the Marconi Co. has a claim. During the war, [fol. 2494] which was after the time when the Deforest Co. transferred such rights to the American Telephone & Telegraph Co., there was grave doubt as to whether or not it (Deforest Co.) had any legal claim.

Mr. Parker: I understood that. The question I put to you, which you have not answered, is whether it ought not to be a part of the Marconi release that they guarantee us against a claim by the Deforest company for things that are identical with the things they gave us?

Commander Loftin: There will be no claim by the Deforest company, because they made the apparatus and the license goes with the sale of it.

Mr. Parker: To the United States?

Commander Loftin: To the United States.

Mr. Garrett: Where we are buying them outright it is simply a question of settlement with them for their original apparatus that they invented themselves?

Commander Loftin: The license goes with the sale.

The Chairman: Commander, do you speak for the members of the board from the other departments in this matter?

- Commander Loftin: No, sir; I have been chosen by my coworkers on the board as chairman of the board.

The Chairman: Are the other members of the board here to be heard?

Commander Loftin: They are here, and I will be glad to have them asked to verify anything I have said; they may think what I have said is a little bit off in some respects.

The Chairman: We will be very glad to hear from your coworkers.

Statement of Mr. Harry E. Knight, Special Assistant to the Attorney General of the United States, Delegated to Represent Him on the Interdepartmental Radio Board.

Mr. Knight: Mr. Chairman and gentlemen of the committee, the questions of some of the members of the committee have indicated the possibility of a lack of full knowledge on the part of some as to the history of these litigations in which the Government may be involved.

The Government, of course, being sovereign, can only be sued by its own consent. After a long consideration of the matter, the Government consented to be sued in certain cases, and the Tucker Act was passed, which enabled the Government to be attacked under a contract. For a long time the question of litigation against the Government in matters involving tort was subject to much controversy. Actions were brought directly against the Government and dismissed because being laid in tort; the Government being claimed by the claimants to have proceeded without right from the claimant, but against his rights, those actions were dismissed as being not properly covered by the law.

There was very considerable doubt often on those points, and there is one very early case of that kind in the Supreme Court of the United States, in which one of our leading justices dissented strongly from the opinion of the Supreme Court, saying he considered that the grant of a patent by the Government and the use of the invention covered by that patent by the Government implied a contract, and he would recommend that the Supreme Court proceed with judgment in favor of the patentee in case the patent were sustained, and as if it had been used on an implied contract. That, however, never became the ruling of the Supreme Court.

Other cases were brought against officers of the War Department or other departments trying to stop their use of a thing for the Government, but on the supposition that they might be reached as individuals. Thus in some cases the article was an invention which was used for the Government, and the people using it were working as officers of the Government. There was, however, the conclusion reached that these officers could be prevented from future acts by injunction, but the Government could not be interfered with in the use of material that it had purchased or

constructed, but the officers could be restricted from further infringement.

That caused a good deal of commotion among patentees, and finally the act of June 25, 1910, was passed, in which a right was given against the Government direct in favor of a patentee when the Government had, without license or authority of the patentee, used the invention. There was no expression in the act which excluded action also against the contractor with the Government.

It was quite a general opinion that the effect of this act was to make the Government a licensee, so that a contractor with the Government would be free, for if he were dealing with a licensee he could not be attacked. It was the general opinion at that time that the Government had appropriated a license. Contractors during the war went largely on that hypothesis, that by the act of June 25, 1910, they were protected. They were dealing with a licensee, and the Supreme Court had used expressions which indicated that. They went ahead and continued to contract with the Government as they had in the past, warranting the Government against any suit of all other patentees. In 1918, however, the Supreme Court rendered two decisions, which entirely changed the view of patentees and other persons. Those were the cases of *Cramp* and *Simon*. The result of those, briefly, was that while the Government could be sued a contractor could also be sued, unless, as found in the *Simon* case, there were such relations as to make the contractor a mere contributory infringer. In other words, the Government was the real infringer and should have been the one primarily attacked.

Before that time, and fearing that that might be the outcome of the suits, various contractors of the Government, and the DeForest Co. was one of them, had represented to the Secretary of War the dangers that they were getting into by these large orders given out by the Government, and their warranties that were given to protect them against an unknown situation, because radio patents, being a new art, were coming out constantly. There were hundreds of applications in the Patent Office and thousands of patents were being issued. The contractors became very nervous and they asked that they should be relieved of this situation, and that the Government should assume the burden of it. The Government then assumed a different attitude in mak-

ing its contracts. The Government was at war and did not [fol. 2496] want its contracts held up, didn't feel that it could seize all these factories and have its matters held up; it wanted the individual initiative and help of the factories. So it began itself to assume the responsibility and warrant the contractor, and then came along the act of 1918 and made the Government the sole infringer and relieved the contractor.

Before the war started, the situation in radio patents began to be somewhat distinct from that of patents generally. Of course, in a country like this which depends so largely on industrial progress and has given so much favor to its patent system, all the different devices which had been used by the Government had been affected by patents, and had been for years affected by them. But radio was a different situation. It was practically a new art, Marconi's early experimenting was in 1895, some 25 years ago, and his fundamental patents have only recently run out. Indeed, one that he has claimed as fundamental only runs out this year.

Here is a situation that presented a constant development on a great many different lines, interweaving lines, lines which if they had been sent to a court would have necessarily been taken up by piecemeal. Take for instance one of the cases cited by one of you gentlemen. If Marconi had attacked one of these contractors in southern New York district and DeForest had attacked along the same line another contractor in the State of New Jersey, and so on throughout the United States. Of course the courts give a good deal of leeway to the Department of Justice in defending the Government in such cases where the rights have been so split up, but inevitably even if sufficient time had been given the Government to defend all these litigations, we should have had before we got through hundreds of accountings, and with the difficulty that each accounting would have taken very little cognizance of what had taken place before. Accounting is a very technical thing, and it is handled along a very unusual way.

There was a case recently in New York where a suit had been brought under three different patents—two claimants, three patents—three claimants against one victim, and the patents were sustained, and the case went to a master. Both cases were referred to ex-Judge Lacombe, a judge who has had tremendous experience in this class of litigation. He

was appointed to hear and determine the case. He reached a basis of accounting which went in two or three very peculiar directions, but he worked it out very thoroughly and then it was brought before a court, and the way he reached his conclusions—and his conclusions were all attacked—and without entering at all into the merits of the case (the matter is still subject to judicial determination).

Judge Mayer has used a very different method from that that was reached by Judge Lacombe. Different judges have very different views of what should be done on accountings, and back of all that is the question of what a patent really means. We find, for instance, in Marconi's four circuit toning patent an entirely different decision reached in the second circuit from that reached in the far western coast circuit. So that if this had gone up, we should have encountered numerous accountings and copending cases. And this is much more difficult because of the unusual number of claims pending. There had been brought in 1918 a large number of claims, but we knew that there [fol. 2497] would be many more, because patents were issuing constantly. We have had brought before this board patents that were of very recent issue. So that the principal claimants, the Marconi Co. and the DeForest Co. and the International Radio-Telegraph Co., all urging their claims before the War Department, agreed that the matter might be referred to some joint conference of representatives of the War, the Navy, and the Justice Departments, they being the principal ones concerned, to see whether some satisfactory result could not be reached without litigation. They all had their claims that they could present through the Court of Claims and all through the country in the district courts. But they were willing to submit their claims to a board, and I must say that these patentees and these concerns interested with the patentees, have shown throughout a most conciliatory attitude toward the Government. In nearly all instances there has been no disposition shown to press the Government unduly, or take any advantage of it, or to ask for an unreasonable amount.

The Chairman: There has not been a case of gouging.

Mr. Knight: In no case whatever has there been any gouging or any attempt at it.

So, members of the War Department, the Navy Department, and the Department of Justice came together

and called themselves the interdepartmental board, just to have a name to do business with, and to forestall future controversies they sent notices to every one who might have a claim.

The Chairman: Have you a copy of that notice?

Mr. Knight: Yes, sir. It is among the papers here.

The Chairman: Will you kindly give it to the reporter.

Mr. Knight: I think the chairman intends to file all of those papers.

The Chairman: Very well.

Mr. Knight: A number of them responded.

The Chairman: You need not take the time now, Mr. Knight. You can give it to the reporter afterwards.

(The notice referred to is as follows:)

February 12, 1919.

SIR: The board considering the claims of owners of patents for radio inventions asserted to have been used by the Government has been referred to so large a number of patents that unless the field of investigation be narrowed materially the work of the board will be greatly protracted and a satisfactory adjustment extremely difficult or impossible to reach.

Since it is the purpose of the board to expedite its work and reach a conclusion with the least possible delay, and this also being the desire of the patent owners concerned it has concluded to ask these patent owners to cooperate in reaching that object by giving due consideration and answers to the following questions in such manner as they think will render the most assistance to the board:

(a) What patents owned or controlled by you are basic adjudicated patents or are nonadjudicated patents that you consider are generally recognized as basic and which you regard as having been employed in standard practical apparatus that has been actually used by the Government? (Identify the patent or patents by number, date, name of patentee, and identify as definitely as practicable, the type of apparatus in which you consider said patents involved, and how involved.)

(b) If you should obtain a settlement based on the patents named in answer to (a), will you lump all other patents owned and controlled by you in that settlement without further claim for royalty on these other patents so lumped? [fol. 2498] (c) What patents owned or controlled by other

companies or individuals do you regard as basic adjudicated patents or as well-recognized basic nonadjudicated patents that should be taken into account by the board in considering the general settlement of royalties? (Give name, number, and date of patents, by whom owner or controlled, type of apparatus in which said patents are involved, and how involved, so far as information on the subject will permit.)

The board is of the opinion that only by a response to the subject matter of the foregoing inquiries given in the most liberal spirit with due consideration for the patents and claims of others can it hope to arrive at any early conclusion or settlement of the matters involved and begs you to have these considerations well in mind and earnestly cooperate with the board toward reaching an early settlement.

Mr. Knight: A number made no answer. A number said they had no claims against the Government. Those were these: The Federal Telegraph Co., General Radio Co., Liberty Electric Corporation, Moorehead Laboratories (Inc.), American Radio & Research Corporation, Westinghouse Electric & Manufacturing Co., and Kilbourne & Clark Manufacturing Co. These companies all stated that they had no claim for infringement. There were 25 claimants, however, who put in claims for patents. Of these we refused to consider one because we didn't consider it radio at all, leaving 24.

(The papers referred to are as follows:)

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The board is of the opinion that only by a response to the subject matter of the foregoing inquiries given in the most liberal spirit, with due consideration for the patents and claims of others, can it hope to arrive at any early conclusion or settlement of the matters involved and begs you to have these considerations well in mind and earnestly co-operate with the board toward reaching an early settlement.

May 15, 1919.

Referring to your recent letters to the Interdepartmental Radio Board concerning the matter of claim for infringement of radio patents owned by you, the board now requires additional information, and requests that the following questions be answered at the earliest possible date:

(a) Have you granted any licenses, now expired or still existing, under the patents listed in your letter?

[fol. 2499] (b) Are the licenses of such a nature as to permit the licensee or sublicensees to manufacture and to sell to the Government for its use without royalty?

(c) Names of such licensees.

(d) Effective dates of such licenses (dates beginning and dates expiring).

(e) Are you a licensee under any patents owned by others, which license permitted you to manufacture and sell to the Government for its use (past and existing)?

(f) By whom granted?

(g) Effective dates of such licenses (dates beginning and dates expiring).

(h) Under what patents?

(i) Will you kindly furnish a copy of any license above referred to?

This information is necessary to the board in order to avoid making allotments on royalties to the wrong parties.

It is desired that the response shall be as of April 15, 1919.

Mr. Frothingham: You sent these notices to all the 25 claimants?

Mr. Knight: No, sir. We sent them to all that we supposed might make a claim.

Mr. Frothingham: And you thought there would be some likelihood of recovering if they went before the Court of Claims?

Mr. Knight: Yes, sir. I might say this, that those of us who have been devoting our consideration to this art have estimated, but only roughly, whom the principal patentees are. We know who the patentees are, of course. We know those who have patents of merit. For instance, no one would think of omitting the Marconi Co., or the DeForest Co., and so on. So we sent out this list and the result was that it was trimmed down to 24 claimants. And I would like briefly, if it please the committee, to revert to these several claimants, because it will bring this thing up to what it will result if settled in this way rather than by litigation.

The Chairman: The committee would be very glad to have you state that.

Mr. Knight: First, the Vreeland Apparatus Co. (we have these numbered just as they appear on our books, the order does not show when the claim started or the importance of the claim) made claim under four patents. Their claim was one of very considerable difficulty. The Government was more or less involved by their claim. Most of you

remember that during the war the Atlantic Communication Co., representing in this country the German Wireless Corporation, was succeeded in this country by the custodian. Among its effects was found an agreement with the Vreeland Apparatus Co. for the use of its invention, and that was seized or bought by the Government custodian among other claims. It was considered by the Munitions Patent Board that that contract (the Government having taken this license over), that that license had lapsed on account of failing to continue to make payments for license fee. So the claimant came to our board to ascertain whether the patents were valid, whether the Government was bound to respect them by reason of this patent, or otherwise, and whether the Government had used the apparatus and the patents. Two of the patents concerned were subject to broad patents controlled by the International Radio Co.

I will not bother your committee by going over the months-long study by the board of the patents, but we reached the conclusion finally that the situation was not so clear that the committee could recommend the Government make any payment on this part of the claim. The remainder of the claim was under patents relating to oscillators. The patents had lain idle for a number of years, and were [fol. 2560] only brought up before our board as an after-thought, and we didn't feel under those circumstances that we should be the first to say that the Government should pay something for such patents, and we rejected the claim in toto, and it will go to the Court of Claims.

This is one case of a claim where the board was not able to settle. It was a claim so large under facts of such doubtful merit that we haven't thought it wise to prejudge before it goes to the court.

The next one on our list is the Marconi Wireless Telegraph Co. They have numerous patents, but they offered to waive all their claims if we made a satisfactory claim on a few, and they brought to our attention four as of particular merit. Those four patents are all fundamental.

They have all been sustained by the courts, and the Marconi Co. made very pointed representation to this board that they should have a special position because they were the only company holding claims that had been held to be fundamental, and they have all been sustained.

The Chairman: Lieut. Commander Lofton said that your board sustained three, and one had not been sustained.

Mr. Knight: Yes. I mean sustained by the courts. They had all been sustained by the courts. One was called the Marconi reissue patent, which is the fundamental patent for wireless telegraphy. The second was his improvement for tuning the two circuits at each end. The third was Lodge's patent for tuning the antennae and adjusting it by means of a coil. I speak of it in as simple terms as I can, because I imagine we are not all familiar with radio language. And the other was in connection with the Fleming patent, what is known as the Fleming valve. These were all important patents, but the first of them, while sustained by the court and held fundamental, had been held not infringed by the modern wireless systems. So we found no possibility of going beyond the courts in that, and we refused to allow the Marconi Co. on that. The other claims involved finding what the Government had done. They were evidently valid. They had been defended by various companies at enormous expense and held infringed.

(Thereupon a recess was taken until 2 o'clock p. m.)

#### After Recess

The committee met, pursuant to recess, at 2 o'clock p. m.

#### Statement of Mr. Harry E. Knight—Resumed

Mr. Knight: It has been suggested during the recess that in the Dent Act, to which this bill is proposed as an amendment, in order to avoid certain difficulties in the comptroller's office, who is the one man in the United States who must be obeyed by everybody, the words "on a fair and equitable basis" were inserted in the act after the words "to adjust, pay, and discharge," and the suggestion is that that addition be made to this bill also so as to prevent any too rigid interpretation by the comptroller of the actions of the heads of departments that are taken under this act.

Before taking up a little further in detail the various claims, I want to say one word about the number of the [fol. 2501] claims. I think, perhaps some confusion has been created in the minds of some members of the committee as to the number of claims. It has been stated there were some 2,500 patents.

The Chairman: Two thousand seven hundred.

Mr. Knight: Or perhaps 2,700. Each of these patents has what is called a number of claims in it so that there might have been brought before us, perhaps, 10,000 claims to separate elements of radio apparatus. A very large proportion of those patents, of course, have no relation to anything the Government or anybody else ever did, and I should say fully half of them nobody ever did anything with at all. Fifty per cent of all patents are merely unsuccessful dreams and probably the usual proportion of radio patents is the same. The committee has, however, examined all of these patents. Most of them it discarded from any further thought. Those that seemed to be important it has proceeded upon, and of those that were important, where it has received a claim on invitation, it has taken action on the claim, either favorably or adversely, except as to one or two cases not yet determined. After hearing from claimants, there were several hundred patents still before the board which the board had to consider of more or less importance.

Those were reduced, after much discussion, to about 150 patents, and by a further process of elimination, either by agreement with the claimant or by direct action of the board, those were all reduced to some 27 patents as the ones that were worth while passing upon at all. But with regard to the question of matters that may hang over, which has been the subject of some discussion here, the board is fully convinced that by this settlement, not only shall we save the Government much money, as to the details of which I think the Special Assistant to the Attorney General here, who is in charge of patent matters generally of the Government, can give the committee better information, but we shall have settled every claim capable of settlement either now present or which may become present on all of the activities of the Government in radio matters since the year 1910, which is the time of the beginning of any possible claims.

Mr. Hull: Right there, I thought you said this morning there were some claims not included in this settlement.

Mr. Knight: There are. Those are claims we have, with our best judgment, gone over and considered not capable of settlement; that is, not ready to settle, and they will have to go into court. I do not mean to say we have settled every claim on which suit may be or will be brought, but every-

thing on which we think a suit can justly be brought with a rendition of a verdict favorable to the claimant.

Mr. Hull: The Deforest people never came to you at all?

Mr. Knight: Yes, sir; we have had perhaps 25 arguments from them. Their claim has been in the Court of Claims since 1919.

Mr. Hull: You do not think they can justify their claim?

Mr. Knight: We do not. I do not mean to say in toto. They undoubtedly have a claim to some extent, but to the extent that they claim we were absolutely unable to reach an agreement with them. The question with some of these people is whether they have any claim at all. The question with others is, admitting they have some claim, how much can they justly be settled with, and where, for instance, with the Deforest Co. asking for \$400,000 and we thinking [fol. 2502] the total sum they should have is \$20,000, we are so far apart that we can not make a settlement with them. I do not instance those figures as the exact sums, but simply as an illustration.

The Chairman: But you contend that if they have any claim they can go to the Court of Claims and have that adjusted?

Mr. Knight: Yes. There is no attempt here to deprive a claimant of his rights in the Court of Claims. Our only attempt is to make settlements which will save the Government money and at the same time give these claimants their money within a reasonable space of time.

Mr. Hull: It is not exactly true that you have settled all claims?

Mr. Knight: No, sir.

The Chairman: Mr. Hull, they did not say this morning that they had done that.

Mr. Hull: No; but I understood him to say just now that this would practically settle all claims.

The Chairman: Except those of the Deforest people and one other company.

Mr. Knight: If I said that, then my language is incorrect.

Mr. Hull: Now, you say, "for all time." Let me clear that up in my own mind. You, of course, do not mean to say that you have settled a claim against the Government for an improvement that has not been made?

Mr. Knight: No; all claims that can be made for anything that has happened up to the date stated in the settlement.

Mr. Hull: Will this settlement give the Government the right to go ahead and use all these patents that we have settled for in this bill in the future?

Mr. Knight: In the future; and the bill provides that we shall have the right to do that, if possible. Of course, it is not always possible to make an arrangement for a future right. Sometimes the patentee is uncertain in his desires. He will want more than the Government is willing to give him, and the Government may finally say, "See us in the Court of Claims."

Mr. Hull: We are settling with the Marconi Co. under this bill?

Mr. Knight: Yes.

Mr. Hull: Does that give us the right to go ahead and use those patents in the future?

Mr. Knight: No, sir.

Mr. Hull: We have to pay for that in the future?

Mr. Knight: Yes, sir.

The Chairman: This only enables you to settle up to the time this agreement is finally acted upon by the President of the United States.

Mr. Morin: You have allowed for every case where there can be any substantial recovery made, have you not?

Mr. Knight: That is our judgment; yes. We have even gone so far, in some cases, as to allow something on account of the loss of the Government in litigation expenses; that is, we have had that in mind. It is a thing you can not reckon in exact figures, but it is always a thing we have had in mind. Where there is some doubt as to whether the claimant can sustain his patent, but we think the court may resolve those doubts in his favor, we have also had the fact [fol. 2503] in mind of the saving that the Government is making in litigation expenses.

Mr. Hull: Do you base your settlement on basic patents or do you base it on the service that the man rendered in getting up a new combination?

Mr. Knight: We have considered the size of the invention in its several aspects; the size so far as it may involve expensiveness of apparatus; its size so far as it relates to its position in the art. Where it is a very important patent we have paid much more regard to it, as we think the court

would, than to a less important patent. Indeed, our whole process of mind has been to try to find out, as far as we could, what the Court of Claims, which would be the tribunal hearing these cases against the Government, would do in the way of awarding fair and just compensation under the present acts of Congress.

Mr. Hull: They never award anything except for a basic patent.

Mr. Knight: Oh, yes.

Mr. Hull: They do?

Mr. Knight: Yes; wherever the Government has without right or license from the inventor used an invention, they make an award.

Mr. Hull: Whether he had a basic patent or not?

Mr. Knight: Yes, sir; the law of 1910 says nothing about basic patents. It says that wherever the United States has used an invention without right or license or authority, whatever the words are, from the inventor, etc.

Mr. Hull: As I understand it, and I may not be right about it, most patents are not basic at all, but are simply combinations of old principles.

Mr. Knight: You might almost say that all patents are combinations.

Mr. Hull: Not all; there are some basic patents, as I understand it. A manufacturer could manufacture any of those patents that are not basic, and the man who has the patent can not prevent the manufacture unless he has a basic patent.

Mr. Knight: No; that is not the law, sir. Within the limit of his right, the owner of a limited patent is as fully protected as the man who owns a patent as broad as the earth. The measurement is not of the quality of his right, but the extent of it.

The Chairman: And if anybody infringes that improvement of a basic patent, he is liable for that infringement?

Mr. Knight: Absolutely; if the owner of a basic patent should copy—supposing he is not merely a patent owner, but a manufacturer—Smith's patent for some little improvement and the court held, however small that improvement was, that it was still an invention, then the owner even of the basic patent will have to pay him.

Mr. Hull: But if the man could prove that the patent which he was copying was not fundamental, that it was

just simply an old principle applied, he certainly would have the right to use it.

Mr. Knight: No. If that goes to the extent of finding—

Mr. Hull (interposing): That is, as I understand patent law.

Mr. Knight: If it goes to the extent of finding that the patent is invalid on that account, yes; but a court can not find, first, that the patent is valid, however limited; second, that the defendant has used it, and still refuse to find the [fol. 2594] defendant guilty, and find him guilty in damages if they can be ascertained.

Mr. Hull: I do not understand why the Government should reimburse, unless it would be necessary, under the same circumstances, for a private corporation to do the same thing.

Mr. Knight: That is perfectly true; and there is no award that would be made without that.

Mr. Hull: Most manufacturers, or a great many of them, simply go and steal another man's patent right along, and if they have enough money they can get away with it, especially if it is against some poor fellow. They can do it right along, and they do do it.

Mr. Morin: Are you not doing the same thing that you would do with a private corporation?

Mr. Knight: Our findings, of course, are based on precisely the rulings that would be made against any corporation or any user of an invention.

Mr. Frothingham: You are acting under something that Congress passed in 1910.

Mr. Knight: Yes; in 1910 and 1918.

Mr. Frothingham: And it is up to Congress if anyone is to blame.

Mr. Hull: I think when that act or an act similar to that was passed I was not here; and they contended that the Government should reimburse the men holding the patent for the value of the improvement to the art, irrespective of whether he had a fundamental patent or not. I have always thought we should not do that. If a man, of course, has a fundamental patent, we are liable for damages. If he has not, I do not see how he can set up a claim for damages, because, as a matter of fact, when you examine the cases where the corporations have fought them out, the courts have ruled right along that unless a man can prove

he has a fundamental, basic patent he can not recover damages.

Mr. Knight: I think, perhaps, the cases you have in mind are those in which the courts have given less value to improvement patents.

Mr. Hull: I will cite the cases in reference to the internal-combustion engine—the Selden patents and all those cases.

Mr. Knight: That is a very good illustration. The Selden patent was held in the final decision by the court of appeals to be limited to a specific form of engine. It was held to be so limited a claim that the modern automobile had drifted away from it and the patent did not cover them. It was not held that because the patent was limited a defendant infringing it did not have to pay, but it was held that the defendant did not use it because the invention was so limited.

Mr. Hull: What he used was not an infringement; that is what they held.

Mr. Knight: Exactly.

Mr. Hull: That what he used was not an infringement because the principle was old.

Mr. Knight: Yes.

Mr. Hull: And that the patentee did not invent anything.

Mr. Knight: There is the distinction. You see the narrower you make the claim the less chance there is that the defendant will have used it; but however limited the claim, [fol. 2505] if the defendant has used it, then there has never been a decision that he does not have to pay for it.

Mr. Hull: But the claims of a lawyer in getting a patent are always very broad. He makes them as broad as he possibly can.

The Chairman: The basic patent is not always the most important. You will remember that the steam engine was a very valuable basic patent. Then George Westinghouse came along and patented a little airbrake, which made it possible to run that train at an enormous rate of speed. He became very rich. His patent was a comparatively simple thing, and yet that patent was as valuable, if not more valuable, than the basic patent.

Mr. Knight: This question of basic patents is largely an unprofitable one for discussion, because a basic patent may be basic for a few minutes and then is set aside by another basic patent. We had an instance of that in this art. For example, Fessenden had made his very valuable and very clever improvements in electrolytic detectors, which he

called a liquid barator. It was thought to be the only thing that was a substitute for the old forms of insensitive and difficult working detectors.

Mr. Hull: I do not want to go into a discussion of the basic patents and all that. I am not lawyer enough to do that. The point that I want to get at is this: In the settlement of these claims are we paying for patents or supposed-to-be patents, which they claim are patents, but they are not really patents, but they are registered and all that? I am pretty sure, if I remember aright, that Secretary of War Baker argued that we should do that; if anybody improved anything and had spent his time on it, we should pay for it—that is, if he had patented anything that could be sustained in the courts.

Mr. Knight: We have examined to see whether he had a valid patent, and then we have examined to see how broad that patent was, what its scope was, and we have tried to find out how many and what apparatus the Government had made which were under patent. That gave us some basis of estimating what payment should be made. If we thought the patent invalid or insignificant, that the improvement was not worth paying for, we have so declared; but if it was a substantial improvement and the Government used it and had the advantage of the invention and it was a legal claim which the Court of Claims would allow, we have, in that case, favored the claim.

Mr. Hull: That is all.

Mr. Wright: As to the Marconi patent, just how did you arrive at what was the proper amount of award to give for the right to make?

Mr. Knight: A wireless set has two very well-defined things. We have the transmitting end and the receiving end. There may be one transmitter and a number of receivers. Some inventions are peculiar to the transmitter and some to the receiver. Also, there are fundamental patents to each that go to the entire structure and some that simply deal with parts of the structure. You take, for instance, an ordinary radio installation and take the Marconi 4-circuit tuning patent. Marconi, before this other invention came up, had devised radio telegraphy. He now removed the spark gap, the device that put the oscillations into the vertical wire, from the vertical wire and put them in a side circuit and then tuned those two circuits together, [fol. 2506] so that the power would be efficiently trans-

mitted from one to the other. Of course, you can tune two electric wires just the same as you can tune two wires in a piano, so that when you touch one the other one responds. He took a patent for that.

We had to consider how much of those were used in our transmitters and how much were used in our receivers, and then we had to find out what other inventions were in it, because there were other inventions also that related to the entire transmitting set and some that related to parts of the set. The Court of Claims has been somewhat arbitrary in its fixing of awards that should be made to inventors. In ordinary cases against a private individual or corporation the court ascertains the entire profit that has been made by the defendant or the entire loss that has been suffered by the plaintiff or the damage that may have been caused to the plaintiff, finds out the biggest figure and gives it to the patentee. This board does not proceed exactly on that basis. It is not a question of damage to the plaintiff or what profit—the Government makes no profit. The law says that the court shall investigate and determine what shall be due and proper compensation. The law does not use the word “damages” nor “profits.” Proceeding on that basis the board investigated and took testimony to ascertain what would be a fair amount.

We went on the basis that the general run of Government contracts during the war were made on a cost-plus 15 per cent basis. As a rule, the courts, outside of the Court of Claims, when they determine the amount that shall be awarded for profit, allow the whole profit, to go to the inventor unless there is some particular reason for diminishing it. In this case we had a number of reasons for diminishing it. We had a number of other awards to consider. Taking the total profit to the contractor dealing with the Government at 15 per cent on his cost price we had to fix a sum that we could deal with for dividing among these patentees. Having found, say, that such and such a set would have cost the Government a million dollars and that the profit on it was, say, \$150,000, and the patents to be considered were Marconi's 4-circuit tuning, telephony patents, and so on, then we determined the relative value of these patents in the set. It varied some in different sets. In some sets the principal part of the thing would be the heterodyne, in others the principal object was to use it for

telephony, and so on, and so we had to give different weights to different patents at different times.

The Chairman: What does heterodyne mean?

Mr. Knight: What is ordinarily meant in music by beats. That is a very interesting patent. They had long desired to use in wireless what is known as the continuous wave, but when a continuous wave came over there was no means of receiving it unless you had some mechanical or other interrupter, and thus you lost a lot of the energy. Prof. Fessenden solved the problem by working with these high-frequency electric waves, so that if you were sending at 100,000 frequency per second and you put in your local circuit, going over the same wire, say 99,000 per second, then you would have traveling on this wire those two frequencies, one of 100,000 oscillations and one of 99,000, and the difference between the two, namely, 1,000, would be the frequency heard over the telephone. That is just about the [fol. 2507] natural frequency of the telephone diaphragm. He got a broad patent for that. In many of the systems used by the Government that is a very important means of receiving. In a great many of these cases, where it was so important for receiving the continuous wave, we have allowed a larger proportion to the heterodyne. In other cases, where the principal object was to use it for the telephone, we have allowed the telephone patent a greater weight. They have all had to split up the 15 per cent between them, because that is the limit we have been willing to go.

Mr. Hull: Fifteen per cent of the cost of the article?

Mr. Knight: Yes, sir; of the cost to the Government.

After all, the courts have always said that when it comes to these questions we must do a lot of guessing. We have exercised the privilege of the court in guessing once in a while. We have sometimes had to guess what the article was that the Government used. We have taken the best evidence we could get. We have pulled up sailors, officers, soldiers, and everybody else to try to find what this particular thing was, and we have found it.

The Chairman: Is it 15 per cent of the amount that the company or the corporation or the individual has put in a claim for?

Mr. Knight: Where the Government has bought an installation, say, for \$100, we have estimated \$15 of that was

profit to the contractor, and an amount similar to the profit to the contractor has to be divided between the inventors whose inventions he used.

The Chairman: That is exactly in line with what Mr. Hull suggested.

Mr. Knight: We have not always done that, because in some cases we have found that the prior art, as it is called—that is, the old art that everybody has a right to use—should receive its share. Thus the Marconi Co. was very much troubled because, having allowed them a percentage during the period of the life of the Lodge patent to their profit, we continued to take off that same percentage, but to the profit of the Government, after the Lodge patent expired.

The Chairman: It has been very interesting and we thank you very much.

Statement of Capt. Guy Hill, Officer in Charge of Radio Development Section, Office of the Chief Signal Officer of the Army, and Member of the Inter-Departmental Radio Board.

Capt. Hill: The problems of the War Department in radio are very similar to those of the Navy Department, except, of course, our work is different in not having practically any ship radio. We have aircraft, tanks, and a large number of portable sets for the Army. The inventions that have been used in the War Department apparatus are practically identical with the inventions that have been used in the Navy Department apparatus, except that we have not used them to as great an extent.

I think Commander Loftin, Commander Hooper, and Mr. Knight have summed up the work of the board and the way that the board has used these patents, so I have not anything definite to add, unless you have some specific questions.

[fol. 2508] The Chairman: You have heard their statements?

Capt. Hill: Yes, sir; I have been here all during the hearing.

The Chairman: And you concur in their findings?

Capt. Hill: I concur in the findings and in the statements which they have made before the committee.

Mr. Wright: You also concur in the statement that there has been a great deal of detail involved in the board's investigations?

Capt. Hill: I certainly do.

The Chairman: Is there any member of the committee who would like to ask any questions? [After a pause.] If not, we thank you very much.

Capt. Hill: I should also add, Mr. Chairman, that Maj. Young, the other member of this board from the War Department, is in full accord with the statements of Commander Hooper, Commander Loftin, and Mr. Knight.

The Chairman: I understand that he has been called away on account of the death of a member of his family. Otherwise he would have been glad to have been here and give his evidence along the same line?

Capt. Hill: Yes, sir. He was here a while this morning, but had to leave.

The Chairman: We are much obliged to you.

Statement of Mr. Edward G. Curtis, Special Assistant to the Attorney General, in Charge of the Defense of the United States in Patent Litigation.

The Chairman: How long have you held your present position, Mr. Curtis?

Mr. Curtis: Two years, Mr. Chairman, approximately. In that connection, with your permission, I might state how I came to be connected with the Department of Justice, and what my work has been there, so you may understand exactly the basis on which I found the statements that follow.

The Chairman: We shall be glad to hear you.

Mr. Curtis: Following my return from military service I was asked to come to Washington by Attorney General Palmer, to take charge of the defense of the United States in its patent cases.

A great number of patent cases against the Government had accumulated not only under radio patents, but under a great many other patents, and the Department of Justice at that time was not prepared to meet the situation. I came here and formed a department of patent defense, which consists of some 20 or 25 patent attorneys.

During these past two years I have participated in no less than 100 different pieces of litigation involving alleged

infringement of patents by the United States. In the course of these two years I have come into intimate contact with every branch of the departments of the Government which has any particular interest in or dealing with patent matters. Now, there is a foundation for the few remarks I have to make.

First, something has been omitted from the testimony given before you. The modesty of the members of the board [2509] has prevented them from saying what I can. I have watched the board from what might be called an outside position. They have worked with a high degree of intelligence and skill with this very difficult problem, and when they say, without any explanation, that the patent claimants have been docile, be assured the reason for it is that claimant after claimant has been obliged to concede the care and efficiency with which this board has examined the problems before them.

Speaking for the Department of Justice, I am impressed with the business aspect of the situation. It would cost the Department of Justice probably no less than \$500,000 in counsel fees, expert fees, and other expenses to fight through the courts these various claims that this board has succeeded in getting to this point of settlement.

Secondly, I have no doubt whatever that should the efforts of this board fail and the cases go to trial in the Court of Claims, the sum of the awards by that court would exceed the findings that have been made by the board.

Putting these points together, therefore, it is hardly controvertible that if this committee passes the recommendation which is before you, a direct and demonstrable saving of considerable extent will have been vouchsafed the Government.

As to the details of the operations of the board, the complicated wireless instruments which they have studied and analyzed. I do not feel qualified to speak; these matters have already been put before the committee; but I shall be glad now or at any time to answer, so far as I can, any questions which you have to ask.

The Chairman: Does any member of the committee desire to ask any questions at this time?

Mr. Hull: Just one question. What do you estimate is the amount of claims that are not settled by this?

Mr. Curtis: You have touched a very difficult problem there, and I will have to do a little guessing. The situation is this: There are, roughly speaking, two classes of claims, good claims and bad claims. This board has sifted out the wheat from the chaff, so far as it can be done outside of a court, and has determined that certain claims are good and ought to be settled and that certain claims are either bad or at least so doubtful as to make settlement inadvisable. Speaking by and large, these latter claims will probably come up in court, but they are the claims we do not particularly fear. The board has made peace with most of those who had good patents that were infringed, and for the most part has declined to settle only with those who had patents apparently invalid or patents which were not infringed. If those who have been discredited by the board are disgruntled and proceed in the Court of Claims, we have good hopes of confronting them with effective defenses. As to these unsettled claims, I hardly know what to say; they involve claims of some millions of dollars. But, as I said, we feel that in most instances we have defenses against them and look forward with considerable assurance to defeating the majority of those plaintiffs who have not been wise enough to submit to the recommendation of the board. Of course a claimant denied by the board can go to the Court of Claims if he desires. If he does, he will meet the combined strength of the board and counsel for the United States, who will be provided with what we believe are good defenses.

[fol. 2510] Does that answer your question?

Mr. Hull: Yes, sir. Along that line, what as to the future of these claims, does it take into consideration the future use by the Government? Of course, by doing this we admit that the party had a claim against the Government.

Mr. Curtis: Possibly; but I should suggest that you let Commander Loftin answer that question, because it is a phase about which he knows more than I.

Commander Loftin: Do you desire me to say something on that point?

Mr. Hull: Yes, sir.

Commander Loftin: In that connection I am acting in a dual capacity as representing the Bureau of Engineering in radio matters and this board. The Bureau of Engineer-

ing, as you know, purchases the material for radio for the Navy. Now, using the knowledge that this board has gained of the patent situation, we have succeeded in bringing together many of these patents into several of the larger companies and we have succeeded in having those companies practically take care of the Government for the future. For instance, the American Telephone & Telegraph Co. has purchased the Deforest patents—some very important patents to the radio art—and the General Electric Co. has formed the Radio Corporation of America to go into the business of manufacturing radio apparatus and operating radio stations. In doing that they purchased all the Marconi Co.'s interests and combined with those the development of the General Electric Co. and bought out here and there a number of other patents. The International Radio Co., which had a large claim, sold their rights to the Westinghouse Co., so that most of the important patents are held within large organizations and not distributed as they were prior to the commencing of this war. The Radio Corporation and the General Electric Co. and the American Telephone & Telegraph Co. have made an agreement that as far as the Government is concerned any one of those companies can manufacture apparatus for the Government under the patents owned by them, so that gives us at least three competitors from whom we can buy and to expect reasonable prices for the apparatus under a very large group of patents. We also understand that there is in progress an arrangement which will include the Westinghouse Co., so that as far as the future is concerned we feel pretty safe on Government purchases that we will be able to buy from four large companies and can get competition on our proposals for bids.

The Chairman: And at a moderate price?

Commander Loftin: At a modern price; yes, sir; competition from four companies, and in our dealings with them we have always found them willing to supply the Government with apparatus at a very reasonable price.

There are a few other patents that the board has found the Government may be likely to use in the future which are not included in the arrangement among these large companies. In those cases we have secured an arrangement under this settlement proposed to take care of the Government for the life of those patents for a nominal

amount. So, I think it can be safely said that this settlement [fol. 2511] will take care of the future as far as patents which exist to-day are concerned.

Of course, we can not attempt to say as to things which will come after that, but we anticipate, as far as these companies are concerned, that they will give us the benefit of their development; that is, as far as the competition on the part of the four companies is concerned.

The Chairman: I would like to ask you a question. The Dent law, as I remember, provides that a man, in order to get the advantage of that law, had to file his claim before the elapse of a certain amount of time. This provides for a new section passed after the Dent Act was enacted, and there is a doubt in my mind whether that time allowance would apply to this first section, section 6. Do you think it would be advisable to put in the law as we consider it in the House or in the committee a provision that any claim under this section must be submitted to Congress or the proper authorities not later than, say, six months from the date of the passage of the bill? I think the original Dent Act provides for six months.

Commander Lottin: That would include everybody irrespective of time, and I think that should be sufficient, from a practical side. We have practically had before us—and have had for some time—every claim that we anticipate will be brought. The last one of those was probably after that date in the Dent Act.

Mr. Knight: That time ran out in 1919.

The Chairman: I remember that very well. I was one of the conferees on that bill.

Commander Lottin: We have a few claims that were filed after that date, and if that date is going to limit the claims before this board it should be fixed so it will not.

Mr. Knight: Six months after passage of the act would be an abundance of time.

The Chairman: Have you any other suggestion? Could you say three months. These are all war matters and for God's sake let's get rid of the war as soon as possible.

Commander Lottin: I understand, Mr. Chairman, it was four months in the Dent Act, and I think three months in this case would be quite adequate. I do not think there are any more claims and I think three months would be enough.

The Chairman: I thank you very much. What is the name of that case that you referred to?

Commander Loftin: That is the Dent Act.

The Chairman: What is the name of the book?

Mr. Davis: This is volume 1 of Decisions of the War Department Board of Contract Adjustments. That was the board that acted in a semijudicial capacity in enforcing the Dent Act.

The Chairman: This is referred to in that volume as you have suggested?

Mr. Davis: Yes, sir. The Dent Act is printed in this as part of War Department Supply Circular No. 17.

The Chairman: I just want to identify it in the record so that if the committee want to see it we would know just where to find it.

Commander Loftin: Just one other matter. You mentioned this morning some anticipated change in this bill of requiring claimants who do not accept the board's recommendation of proceeding into the Court of Claims within a certain time.

[fol. 2512] The Chairman: That is what I had in mind just now.

Commander Loftin: I thought you meant in the Court of Claims.

The Chairman: If a man does not file his claim in these branches of the Government within the time mentioned in the act I suppose the law provides how soon he may proceed in the Court of Claims.

Commander Loftin: As I understand, there is no limit on that. But he can only claim six years back in his damages.

The Chairman: I presume the moment you begin to interfere with that right in the Court of Claims you immediately enter into trouble, and we have troubles enough on our hands now.

Commander Loftin: The reason we mention that is that we have understood with our claimants right along that whatever happened in the board would be without prejudice, and I was going to suggest if there were an intention of limiting the time they could go into the Court of Claims, it should not be done, as we have never proposed to them that not accepting our recommendation would prejudice the claim.

Mr. Curtis: May I leave you this one thought: That regardless of what may happen in the future, and regardless of the pleasing fact that probably the future is largely taken care of—even if it were not, it would be highly advanta-

geous to the Government in every way to see that this bill passes, since it will undoubtedly insure to the Government a very large saving of money.

The Chairman: We are very much obliged to you gentlemen.

Thereupon, at 3.10 p. m., the committee adjourned until Tuesday, May 24, at 10 o'clock a. m.)

Plaintiff's Exhibit 142.

French Patent for Invention No. 305,060, for "Improvements in Wireless Telegraphy", granted November 3, 1900, to la Société Marconi's Wireless Telegraph Company.

The original exhibit is in the French language. The French patent No. 305,060 is substantially the same as British patent No. 7777 of 1900, granted to Guglielmo Marconi and Marconi's Wireless Telegraph Company, Ltd., (Plaintiff's Exhibit 34 herein) with the following exceptions:

The French patent, page 2, line 3, refers to French patent No. 261,602; the British patent, page 2, line 48, refers to British patent No. 12,039 of 1896.

The French patent, page 5, line 10, refers to French patent No. 283,521; the British patent, page 3, line 27, refers to British patents Nos. 12,326 of 1898, 6,982 of 1899, and 25,186 of 1899.

The French patent, page 7, gives figure numbers as 5 to 8, whereas the British patent, page 3, line 48, gives figure numbers 5 to 11.

The matter appearing at the following places in the British patent are omitted from the French patent: page 4, lines 34-35, inclusive; page 5, lines 35-54, inclusive; and page 7, lines 12-14, inclusive, and line 22.

Tunes Nos. 7, 8, and 9 of the Table entitled "Transmitting Station" on page 6 of the British patent are omitted from the corresponding Table in the French patent. Tunes Nos. 7, 8, and 9 of the Table entitled "Receiving Station" on page 7 of the British patent are omitted from the corresponding Table in the French patent.

Figs. 9, 10, and 11 of the British patent are not found in the French patent.

The claims of the two patents differ from each other: those of the British patent appear in Plaintiff's Exhibit 34 and those of the French patent appear in Plaintiff's Exhibit 35.

**Claimant's Exhibit No. 150**

**PLAINTIFFS EXHIBIT No. 88 H'**

JOHN STONE STONE  
PHILIP B. BARNES  
BOSTON 1905

*Sept 8, 1904*

*June 30<sup>th</sup> 1904*

My dear Arthur:

The chief limitation to the utility of the wireless wire or telegraphy system is that the radiation emanates in all directions from the transmitting wire so that within the sphere of influence of an wireless wire, all other wireless stations are affected by the signal sent from this wire and may not only receive the signal sent from it, but will be interrupted with it if it is the process of receiving signal from any other wireless wire station from which they may be attempting to receive a communication.

This difficulty may be overcome by using transmitting wire giving forth simple harmonic signal waves and receiving other signal waves at stations and capable of receiving simple harmonic signal waves.

In the existing wireless wire stations, the waves sent out and the waves received are complex harmonic waves owing to the fact that the wireless wires are not simple resonators but are capable, upon having their electrical equilibrium abruptly disturbed, of producing a vibration of a

## Plaintiff Exhibit H2

THE STONE STONE  
BOLTS BUILDING  
NO. 10 WALL

considerable number of different frequencies and also are capable of responding more or less freely to a corresponding, large number of different frequencies.

Instead of utilizing the vertical wire itself as the transmitting station or the receiver, I propose to impress upon this vertical wire, vibrations from an oscillator which vibrations shall be of a frequency corresponding to the fundamental of the wire. Similarly at the receiving station, I shall draw from the vertical wire, only that component of the complex wave which is of lower frequency.

If now the fundamental of the wire at the receiving station be the same as that of wire at the transmitting station, then the receiving station may receive signals from the transmitting station, but if it be different from that of the transmitting station, it may not receive these signals.

By such an arrangement it is obvious we shall be enabled to have a large number of vertical wire stations or anchors

2914

*Plaintiff's N 3*  
*Sup Ex F 1*

Boston, July 22, 1899.

Mr. John Stone Stone,  
Phillips Building,  
Boston, Mass.

My dear Stone:-

*June 20*

Your letters of July 18th and ~~last~~ last were received in due course, and have been read with great interest. The "selective" methods of space telegraphy therein described I believe I understand sufficiently to set up and operate them.

Allow me to add that this specialization of the work which Marconi's experiments to date leave in rather primitive condition, is very important, and should be prosecuted without delay by way of further development, and protection by letters-patent.

Yours very cordially,

*Joseph B. Baker*

June 20

ly 18th and ~~20th~~ last were

June 30<sup>th</sup> :

Plaintiff's N 4

being limitation to the

## Claimant's Exhibit No. 151

Fig. 1.

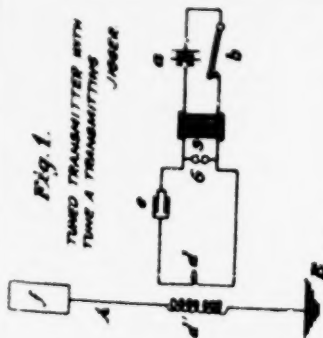
TUNED TRANSMITTER WITH  
TUNE A TRANSMITTING  
JUGGER

Fig. 1A.

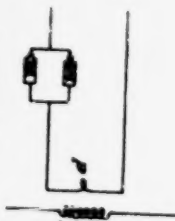
TUNE B TRANSMITTING JUGGER  
AND CONDENSER

Fig. 2.

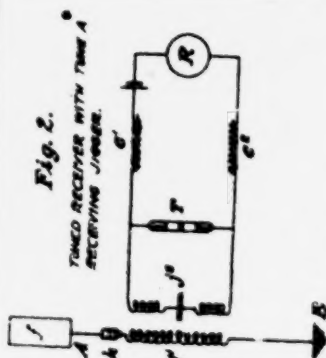
TUNED RECEIVER WITH TUNE A  
RECEIVING JUGGER.

Fig. 2A.

TUNE B RECEIVING  
JUGGER.

Fig. 3.

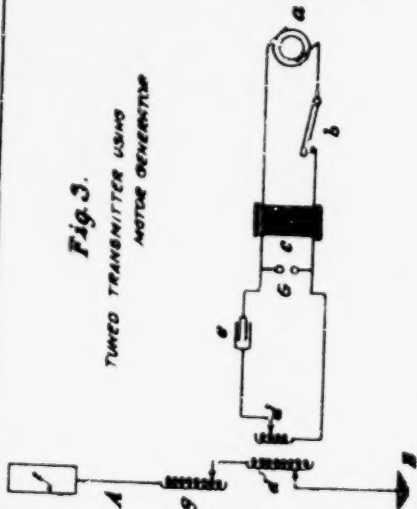
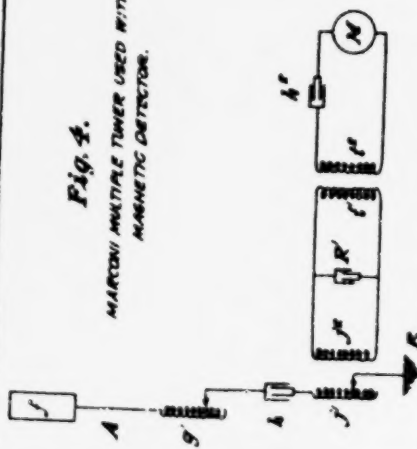
TUNED TRANSMITTER USING  
MOTOR GENERATOR

Fig. 4.

MARTENI MULTIPLE TUNER USED WITH  
MAGNETIC DETECTOR.

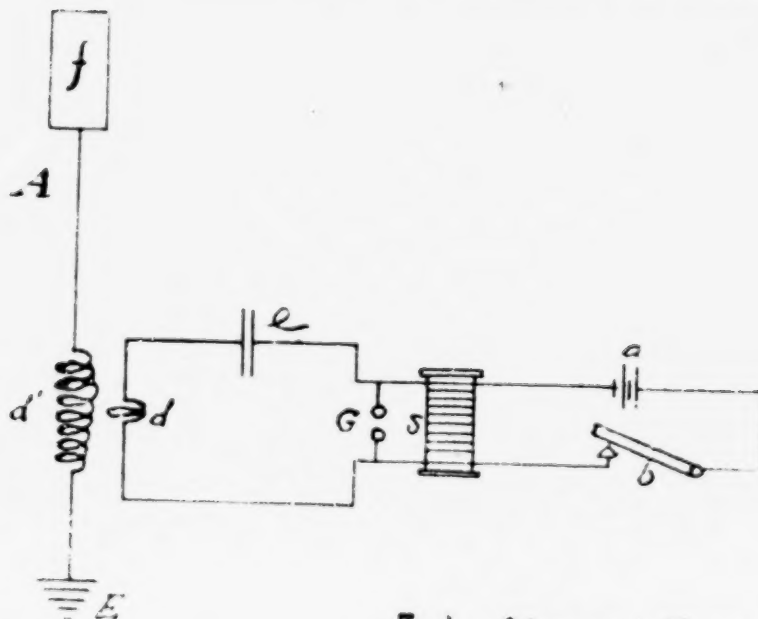
SARNOFF DRAWING  
EARLY MARCONI  
TUNED TRANSMITTERS  
AND RECEIVERS

*Herbert E. Sarnoff No 391*

Claimant's Exhibit No. 157

# FIG 1

TUNED TRANSMITTER  
WITH TUNE A TRANSMITTING JIGGER

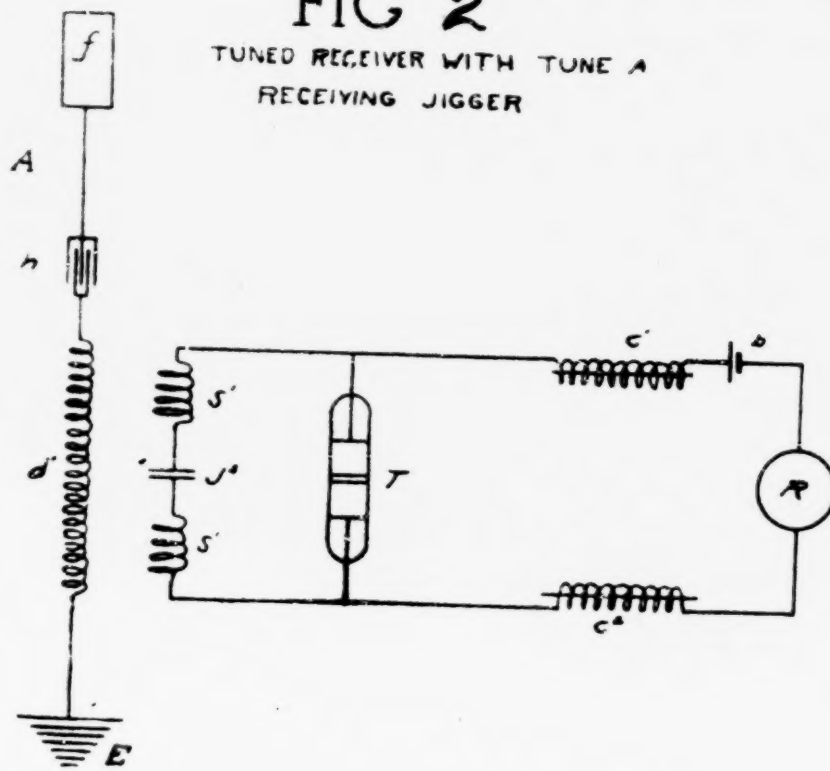


*Reidiff's Exhibit 27 p1*

*Early Marconi Tuned Transmitters*

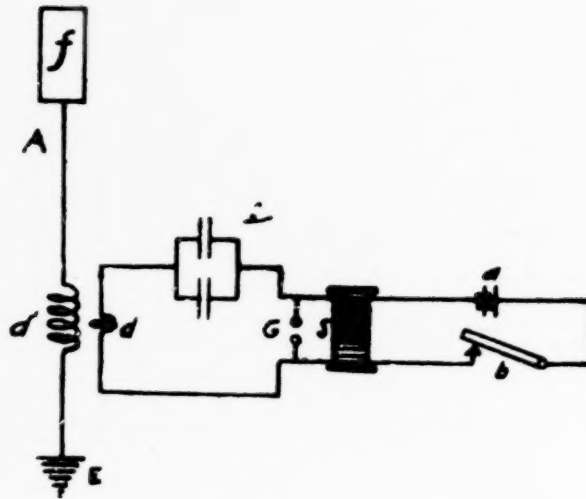
## Claimant's Exhibit No. 158

FIG 2

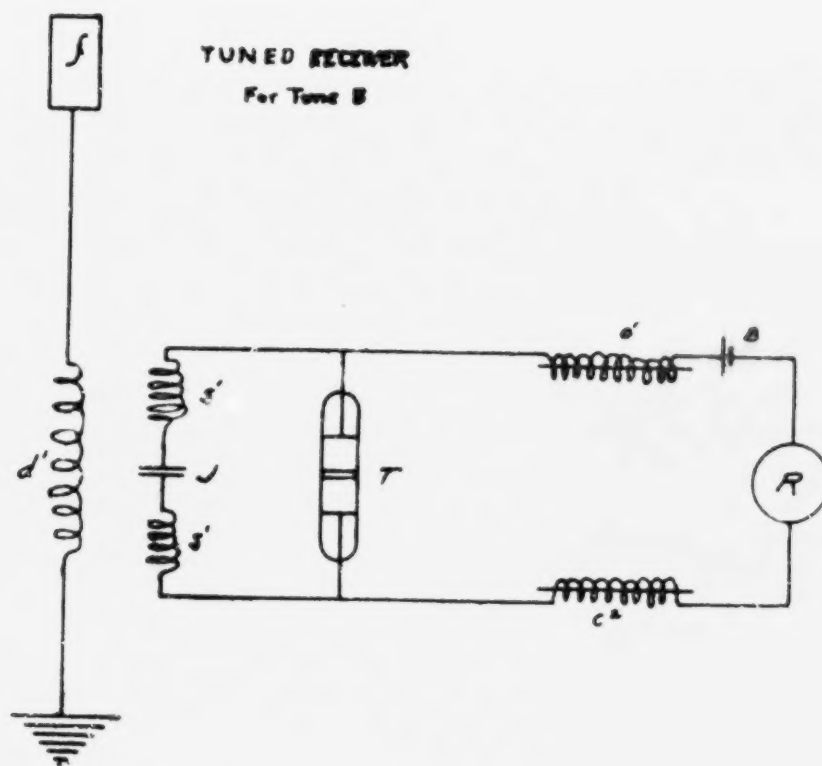
TUNED RECEIVER WITH TUNE A  
RECEIVING JIGGERPlaintiff's Exhibit 277<sup>2</sup>

4-7-10

## Claimant's Exhibit No. 159

TUNED TRANSMITTER  
FOR TUBE B*Claimant's Exhibit 2773*

Claimant's Exhibit No. 160



*Plaintiff's Exhibit 27<sup>th</sup>*

[fol. 2527] PLAINTIFF'S EXHIBIT 171

UNITED STATES DISTRICT COURT, SOUTHERN DISTRICT OF NEW  
YORK

Equity No. 12/31. On Fleming Patent  
No 803,684

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

vs.

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY,  
Defendant

PLEADINGS AND EVIDENCE UNDER SUPPLEMENTAL BILL

Sheffield & Betts, Solicitors for Plaintiff. Darby and  
Darby, Solicitors for Defendant.

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[fol. 2529] UNITED STATES DISTRICT COURT, SOUTHERN DISTRICT OF NEW YORK

In Equity No. 12 31. On Fleming Patent No. 803,684

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

vs.

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY,  
Defendant

## SUPPLEMENTAL BILL

To the Honorable the Judges of the District Court of the United States for the Southern District of New York, in the Second Circuit:

The plaintiff above named, alleges as follows:

*First:* That the Plaintiff, Marconi Wireless Telegraph Company of America, is a corporation organized and

existing under and by virtue of the laws of the State of New Jersey, and a citizen of said State and a resident of the District of New Jersey within said State.

*Second:* On information and belief, that the defendant above named, DeForest Radio Telephone & Telegraph Company, at the time or times of the acts of infringement hereinafter complained of was and now is a corporation organized and existing under and by virtue of the laws of the State of Delaware, and a citizen of said States, and at the said time or times had and now has a regular and established place of business in the Borough of Manhattan, City of New York, Southern District of New York, within the State of New York, where it has committed and is now committing some of the acts of infringement hereinafter complained of.

*Third:* That the above-named plaintiff filed its original amended bill herein against the above-named defendant and another on or about the 28th day of November, 1914, wherein it alleged, among other things, ownership of United States Letters Patent No. 803,684, issued November 7, 1905, to the above-named plaintiff for improvements in Instruments for Converting Alternating Electric Currents into Continuous Currents, upon the invention of John A. Fleming, and charged that the above-named defendant had infringed upon said Letters Patent, and prayed for a discovery, accounting, payment of profits and damages, and for an injunction restraining said defendant from said infringement; that the said defendant duly appeared herein and filed its answer to said original amended bill, alleging, among other things, the invalidity of said Letters Patents, denying the infringement thereof, and setting up other defenses usual in suits for infringement of Letters Patent for inventions; that thereafter issue was joined, a trial on the merits thereof was had in open court, at which a large amount of evidence, [fol. 2530] both expert and fact, was taken by both parties herein on the issues raised; that after further and due proceedings were had, and on or about October 9, 1915, an interlocutory decree was entered herein decreeing, among other things, that claims 1 and 37 of said Letters Patent No. 803,684 were good and valid in law; that said defendant had infringed upon said claims, and granting a perpetual injunction restraining said infringement and an ac-

counting of profits and damages by reason thereof; that subsequently the defendant appealed from said decree and on or about May 8, 1916, the Circuit Court of Appeals for the Second Circuit, after argument on the merits, affirmed said decree; that subsequently and on or about May 28, 1916, an order was entered herein on the mandate of said Circuit Court of Appeals affirming the said interlocutory decree, which orders and decrees remain in full force and effect and unreversed, and all of which will more fully and at large appear by reference to records of this Court and of the said Circuit Court of Appeals, in this suit and to which the plaintiff refers and makes a part of this supplemental bill.

*Fourth:* That the plaintiff has been, ever since the date of said Letters Patent No. 803,684, and now is, the sole and exclusive owner thereof and of all claims for damages and profits for any infringement thereof.

*Fifth:* Upon information and belief and by way of supplement: That the aforesaid defendant, since October 1908, and prior to the execution of this supplemental bill, has unlawfully and wrongfully made, sold and caused to be used within the Southern District of New York and elsewhere within the United States, and is now making, selling and causing to be used within said Southern District of New York and elsewhere within the United States, and threatening to continue so to do, devices or wireless telegraph instruments known as "Oscillions" or "Audion Oscillions", containing, embodying or employing the inventions of said claims 1 and 37 of said Letters Patent No. 803,684, or contributing to embodiment and infringement of the inventions of said claims of said Letters Patent and the rights of the plaintiff thereunder.

*Sixth:* Upon information and belief and by way of supplement, that the said "Oscillions" or "Audion Oscillions" were made and sold and caused to be used as aforesaid, subsequent to the filing herein of the said original amended bill and pending the aforesaid proceedings herein; that the plaintiff, prior to and at the time of filing said original amended bill, was ignorant of the manufacture and sale of said "Oscillions" or "Audion Oscillions" and of the construction and arrangement of said devices and the circuits thereof, and did not acquire any knowledge or sufficient knowledge thereof on which to base any claims in respect

thereto until subsequent to the aforesaid trial under the issues raised by the said amended bill and answer thereto.

*Seventh:* Upon information and belief and by way of supplement, that said "Oscillions" or "Audion Oscillions" are substantially or essentially the same in construction and mode of operation as the audions, amplifiers and devices adjudged by the aforesaid interlocutory decree to be an infringement of said claims 1 and 37 of said Letters Patent No. 803,684, as the same has been construed by this Court and by the Circuit Court of Appeals for the Second Circuit.

[fol. 2531] *Eighth:* Upon information and belief and by way of supplement, that the defendant has derived and received, and is still deriving and receiving from the said manufacture, sale and use of said "Oscillions" or "Audion Oscillions", great gain and profit, but to what amount the plaintiff is ignorant and cannot set forth, and that by reason of said manufacture, sale and use the defendant has deprived the plaintiff of great gains and profits, but to what amount the plaintiff is ignorant and cannot set forth at present.

*Ninth:* That by reason of the premises the plaintiff has suffered great loss, damage and injury, and unless said wrongful and unlawful manufacture and sale by the defendant of said "Oscillions" or "Audion Oscillions" is enjoined by the decree of this Court, will continue to suffer great loss and be irreparably injured and damaged.

Wherefore, the plaintiff prays:

1. That it may have the benefit of the evidence and proceedings heretofore had herein, and of any decisions, orders, decrees or injunctions heretofore entered herein or granted against the defendant herein.

2. That the defendant be required to make full, true, direct and perfect answer (but not under oath, an answer under oath being expressly waived) to this supplemental bill of complaint, and that the defendant be required to pay the costs, charges and disbursements of the proceedings under this supplemental bill.

3. That the defendant and its associates, attorneys, clerks, servants, agents, workmen and employees may be provisionally and perpetually enjoined and restrained by the

decree of this Court from directly or indirectly making or causing to be made, using or causing to be used, leasing or causing to be leased, selling or causing to be sold, advertising or offering for sale, use or lease, or causing to be advertised or offered for sale, use or lease, agreeing or contracting to sell or lease, or causing to be agreed or contracted for sale or lease, supplying or causing to be supplied, installing or causing to be installed, or threatening to make, use, lease, sell, supply or install and threatening to offer or contract for sale, lease or supply, or disposing of in any manner, any devices, known as "Oscillions" or "Audion Oscillions", or substantially similar devices embodying or employing, or contributing to the embodiment or employment of said inventions and improvements or discoveries of claims 1 and 37 of said Letters Patent No. 803,684.

4. That the defendant may be decreed to account for and pay over unto the plaintiff all such gains, profits and advantages as have accrued to or have been earned or received by the said defendant, and all such gains, profits and advantages as would have accrued to or been earned by the plaintiff but for the infringement of the said defendant complained of herein, and also all damages the plaintiff has sustained by said infringement of the defendant, and that the Court will assess the same or cause them to be assessed under its direction, and will increase the same, in its discretion, as provided by law.

5. Or that the interlocutory decree heretofore entered herein and the injunctions heretofore issued herein against the defendant be extended to apply to the aforesaid "Oscillions" or "Audion Oscillions" and substantially similar devices.

[fol. 2532] 6. That the plaintiff may have such other and further relief as the premises and the equity of the case may require and as to the Court may seem just.

Marconi Wireless Telegraph Company of America,  
by E. J. Nally, *Vice-President*.

Sheffield & Betts, *Plaintiff's Solicitors*. L. F. H.  
Betts, *of Counsel*.

STATE OF NEW YORK,

County of New York, ss:

On this 14th day of September, 1917, before me came E. J. Nally, to me personally known, who being by me duly

sworn did dispose and say that he is the Vice-President of Marconi Wireless Telegraph Company of America, the plaintiff named in the foregoing supplemental bill of complaint; that he has read the said supplemental bill subscribed by him and knows the contents thereof and that the same is true of his own knowledge except as to matters which are therein stated to be alleged on information and belief, and as to those matters he believes it to be true. That the reason why this verification is not made by the said plaintiff personally is that said plaintiff is a corporation.

E. J. Nally.

Sworn to before me this 14th day of September, 1917.  
Walter S. Jones, *Notary Public*, New York County.  
(Seal.)

[fol. 2533] IN THE DISTRICT COURT OF THE UNITED STATES  
FOR THE SOUTHERN DISTRICT OF NEW YORK

In Equity No. 12/31. On Fleming Patent No. 803,684

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

vs.

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY,  
Defendant

#### ANSWER TO SUPPLEMENTAL BILL

The Answer of DeForest Radio Telephone & Telegraph Company, the Defendant herein, to the Supplemental Bill of Complaint of Marconi Wireless Telegraph Company of America.

This defendant, answering, says, as to the following correspondingly numbered paragraphs of the Supplemental Bill:

*First:* It admits the allegations of Paragraph First.

*Second:* It admits the allegations of Paragraph Second as to its incorporation and citizenship; but it denies that it has any place of business in the Borough of Manhattan and that it has committed or is committing any of the alleged acts of infringement complained of.

*Third:* It admits the allegations of Paragraph Third, save that the dates given therein as 1915 and 1916 are erroneous and should be 1916 and 1917 respectively.

*Fourth:* It has no knowledge as to whether plaintiff was, at the date of the Supplemental Bill, the sole and exclusive owner of the patent sued on or of any or all claims for damages and profits for any infringement thereof.

*Fifth:* As to the allegations of Paragraphs Fifth and Sixth concerning the alleged infringement, it denies that at any time or at any place it has made, sold or caused to be used, any devices or wireless telegraph instruments known as "Oscillions" or "Audion Oscillions" containing, embodying, or employing the inventions of claims 1 or 37 of Patent 803,684 in suit, or contributing to embodiment and infringement of said claims or either of them or any of the rights of the Plaintiff thereunder; and it avers that the limits of said patent, excluding any and all Oscillation apparatus, are and have been definitely fixed by the Court of Appeals of this Court, by this Court, by the face of the patent itself, and by the prior state of the art; and it further avers that it is doing no business save under its own patents covering the subject matter of the alleged infringement and not previously considered in the prior litigation under the patent in suit.

*Sixth:* As to the allegations of Paragraph Sixth, concerning [fol. 2534] Plaintiff's knowledge of the alleged infringement, Defendant has no knowledge, and leaves Plaintiff to its necessary proof thereof.

*Seventh:* As to the allegations of Paragraph Seventh, that the alleged infringements are substantially or essentially the same in construction and mode of operation as the apparatus heretofore adjudged to be infringements of the patent in suit, as the latter has been construed by this Court and by the Court of Appeals of this Circuit, the Defendant denies the same, and in support of its denial refers to the decision of this Court of July 11, 1917, subsequent to the decision of the Court of Appeals, denying an injunction as to the matters now complained of, although extending in other respects the scope of the injunction previously issued and approved by the Court of Appeals.

*Eighth:* As to the allegations of Paragraph Eighth, it denies that it has derived or received, or is deriving or re-

ceiving from any manufacture, sale or use of "Oscillions" or "Audion Oscillions," any gains or profits; but as to deprivation of the plaintiff of any gains or profits, it is without knowledge.

*Ninth:* It is without knowledge as to the allegations of Paragraph Ninth.

Wherefore, Defendant prays that the Supplemental Bill of Complaint be dismissed with costs.

Philip Farnsworth, Solicitor for Defendant, 149  
Broadway, New York City, N. Y.

Dated New York, N. Y., October 4, 1917.

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[fol. 2535] UNITED STATES DISTRICT COURT, SOUTHERN DISTRICT OF NEW YORK

In Equity 12/31

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

vs.

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY,  
Defendant

New York, N. Y., March 11 and 12, 1919.

Before Hon. Julius M. Mayer, District Judge

March (1919) Term

APPEARANCES:

Messrs. Sheffield & Betts, by L. F. H. Betts, J. Edgar Bull, of Counsel, for the Plaintiff. Samuel E. Darby, Esq., Samuel E. Darby, Jr., Esq., for the Defendant.

PLAINTIFF'S PRIMA FACIE PROOFS

Mr. Bull: Will counsel for the defendant admit that the defendant at the date of the commission of the acts of infringement alleged in the supplemental bill herein, had a

regular and established place of business within the Southern District of New York?

Mr. Darby, Jr.: Yes.

Mr. Bull: Will you admit that this DeForest radio telephone apparatus, bulletin D-16 was issued, published and generally distributed by the defendant subsequent to the filing of the original bill herein and prior to the filing of the supplemental bill herein?

Mr. Darby, Jr.: We admit that the publication was issued and distributed by the DeForest Company prior to those dates, but how generally they were distributed of course I do not know; I am not prepared to state at this time.

Mr. Bull: That is between the date of the filing of the original bill and the date of the filing of the supplemental bill.

Mr. Darby, Jr.: Yes.

Mr. Bull: Will you admit that all the apparatus illustrated and described in said catalogue was manufactured and sold by the defendant within the Southern District of New York [fol. 2536] subsequent to the filing of the original bill herein and prior to the filing of the supplemental bill herein?

Mr. Darby, Jr.: We admit it was offered for sale; I do not know whether it was sold or not.

Mr. Bull: Will you admit that the supplemental bill may be amended *nunc pro tunc* as of its date of filing by inserting paragraph 3, seventh line from the bottom, page 2, "1916" for "1915", and lines 2 and 5, page 3, "1917" for "1916"? Those are clerical errors in the bill.

Mr. Darby, Jr.: These appear to be merely typographical errors and we admit it.

Mr. Bull: Will you admit that the plaintiff is now and has continuously been the sole owner of the Fleming patent in suit since the date of the filing of the original bill herein?

Mr. Darby, Sr.: We have no knowledge as to that; we have no reason to challenge it.

Mr. Bull: Will you admit it for the purposes of this proceeding?

Mr. Darby, Sr.: As far as I know, yes.

Mr. Bull: It is a fact; it will simply save calling a witness.

Mr. Darby, Jr.: If it is a fact we admit it.

Mr. Bull: Your Honor remembers that on the motion an affidavit by Mr. Waterman was filed, a first affidavit, and then a reply affidavit, and a part of those affidavits related to this oscillion matter.

The Court: Yes.

Mr. Bull: If it meets with the approval of the court I will have Mr. Waterman take the stand, have him read what he said in those affidavits as his depositions in this case, simply as a quick way of getting at it.

The Court: I have approved that method on a number of occasions; I think it is satisfactory.

---

FRANK L. WATERMAN, a witness called on behalf of the plaintiff, being duly sworn, testifies as follows:

Direct examination.

By Mr. Bull:

Q. 1. You have testified as a witness in the trial of the original bill in this case?

A. I did.

Q. 2. Will you explain to the court the references in the catalogue which is marked "Bulletin D-3" of the defendant, the references therein to oscillions, and repeat as your testimony in this case so much of the affidavits filed by you on the motion to extend the decree in this case as you desire.

Mr. Bull: First I will offer in evidence the DeForest Bulletin D-16.

Marked Plaintiff's Exhibit 1.

A. The explanation, I think, will be sufficient if I simply read the portions of the affidavits which I gave on the motion which relate to the oscillion.

Referring now to the so-called "oscillation", I produce as [fel. 2537] Exhibit D, DeForest circular marked Bulletin D-16, entitled "DeForest Radio Telephone Apparatus". This bulletin states as follows:

#### "DESCRIPTION OF APPARATUS"

"As shown in the accompanying cuts the new type of DeForest Radio Telephone is distinctly different from all earlier types. In every particular, from principle to detail, it marks a great advance.

"The are used in previous types has been completely eliminated. The generator of the high frequency currents is a modification of the now famous DeForest Audion which has been in use for years in the best commercial wireless stations.

"It is entirely fitting, therefore, that a form of this famous device should have been developed into a generator of high frequency currents for telephoning without wires, for its constancy and thorough reliability are its distinguishing features and these are absolutely essential in a practical commercial wireless telephone.

"When this transmitter is adjusted to the desired wave length no further change is required, it being merely necessary to throw the transfer switch from talking to listening or vice versa."

According to my understanding, the sole "modification" of the bulb employed in the oscillion consists in making it larger with accompanying alterations of detail structural features. All the Fleming valve bulbs, including the so-called three element audion exhibited before the Court, have the property of "oscillating" when properly constructed—that is, if they are provided with a sufficiently high vacuum. This means, of course, that they will oscillate provided they are connected in a proper circuit and supplied with a suitable source of local current. This is not an exclusive property of the Fleming Valve, but is a property of other detectors having the same sort of characteristic curves. For Example, Dr. Eccles in his book entitled "Wireless Telegraphy and Telephony", page 220, states as follows:

"Solid conductors may exhibit instability. The possibility of the phenomenon was deduced by the author from the thermodynamic theory of contacts between substances whose resistivity coefficients are negative, and in May, 1910, he showed before the Physical Society of London a galena detector generating oscillations in an oscillatory circuit. The circuits were precisely those of the arc, Fig. 113. In fact the processes in many detectors are reversible; so that if the application of oscillatory voltage to a detector results in the production of a direct current, the passage of a direct current through the detector results in the production of oscillations in a suitable associated circuit. Conversely,

a device for generating oscillations from steady current can be adapted for rectifying A. C.

### "Vacuum Tubes as Generators

"Like the contact detector, and for a similar reason, some [fol. 2538] samples of the Fleming valve can be arranged to give oscillatory current in a shunt circuit. On account of the high resistance of the gas path the capacity of the shunt circuit must be small, and the inductance large."

The feature of the circuits usually found essential in causing such oscillations to persist is that the circuit connected to the grid element in the three-element type should be sufficiently closely coupled with the circuit connected to the plate element, so that a disturbance in the one is communicated to the other. When this is the case, then any small disturbance, such as the switching on of the battery in the plate circuit, will cause a disturbance in the tuned circuit connected to the grid element, which will set the latter oscillating. These oscillations are at once detected in the plate circuit and evidenced by an alteration of current therein. This alteration of current again disturbs the grid circuit, which continues, therefore, to oscillate and with an increased energy. This oscillation again creates a current variation in the plate circuit, which is again transferred to the grid circuit, and there is thus built up an oscillating current whose frequency is that of the high frequency circuit connected to the grid element, and which increases in intensity until the energy is lost or abstracted at as great a rate as it can be transferred between the circuits. The device, therefore, becomes a generator and it is this generating action which is used in the heterodyne method of reception, and for creating a high frequency continuous oscillation for measuring purposes of various kinds, and as a transmitter in wireless telephony. As I understand it, therefore, the use of one of these vacuum tubes as a generator is simply one of the well-known uses to which wireless detectors having such a characteristic curve as that possessed by the Fleming valves may be put. Its use in this manner is a mere reversal of its normal functions as stated in the passage of Dr. Eccles' work, just quoted, where he says:

"In fact the processes in many detectors are reversible, so that if the application of oscillatory voltage to a detector

results in the production of a direct current, the passage of a direct current through the detector results in the production of oscillations in a suitable associated circuit. Conversely, a device for generating oscillations from steady current can be adapted for rectifying A. C."

Furthermore, oscillion bulbs are capable of effective use as detectors, particularly as detectors of continuous oscillations. These bulbs when properly connected generate oscillations of radio-frequency, and if used at a receiving station are capable of detecting signals sent out by generators or by transmitting stations using continuous oscillations, and also capable of acting as so-called "amplifiers." Due to the combined effect of the amplifying property of the oscillion and the heterodyne effect due to its own generation of oscillations, its effectiveness for receiving wireless signals of both the damped and undamped or continuous type is apparent.

I will now read from the rebuttal affidavit.

[fol. 2539] With reference to the oscillating audion or oscillion, I observe that it is not denied that, structurally, these bulbs are substantially the same as those already before the Court, save that some of them are larger. It should be pointed out that, as a matter of fact, the bulbs supplied with the DeForest amplifiers, as, for example, the bulbs in Defendant's Exhibit A-4, are oscillating bulbs and in the tests upon Defendant's Exhibit A-4, we so used one or more of them.

The instrument in fact has a switch marked "Ultra-audion", and this so-called "Ultra-audion" is nothing but the ordinary audion provided with means of coupling together the two circuits of the bulb so as to permit of generation of oscillations.

This oscillating action not only supplies a means of giving heterodyne reception, the bulb acting both as the detector and the source of local oscillations, but it greatly increases the sensitiveness of the bulb as a detector for the reception of spark signals. For example, it is a common experience to find that when a given signal from a spark or damped oscillation transmitter cannot be heard at all with a valve (either two or three element) operating as a detector without oscillations, a good signal is obtained when oscillations are set up in the bulb, owing to the increased sensitiveness of the detector which results. These oscillating audions

are, therefore, particularly sensitive as detectors, either for damped or undamped oscillations.

In some recent tests made by Mr. Weagant and myself, for example, the signals being sought were those sent from Carnarvon. The so-called "fancy" circuits were being used. So long as the bulb was not oscillating the signals were inaudible, but upon slightly readjusting (but without change of circuit) so that the bulb oscillated, the sensitiveness was so greatly increased that the signals were not only audible but readable.

Further, it is a fact that, whether the oscillating bulb is used as a detector in the receipt of signals or for some other purpose, its operation in so oscillating is essentially a detecting action. The operations going on within the bulb are assumed to be as follows:

The bulb is provided with two circuits, one an oscillatory, tunable circuit, and the other a battery circuit, and some means is provided for "coupling" the two circuits together electrostatically or electromagnetically (such as a condenser or coil common to the two circuits) so that disturbances in one circuit will be experienced to some extent in the other. When the battery circuit is closed, the filament being heated there is, of course, a flow of current, and the establishment of voltages in the circuit. A charge is, therefore, imparted to the oscillatory circuit, which, of course, gives rise to oscillations therein. These oscillations, acting upon the valve in the ordinary way, produce fluctuations of current in the plate or battery circuit. Since, however, this circuit is coupled to the oscillatory or first-mentioned circuit, energy is again transferred thereto from the battery circuit. If the circuits are properly adjusted this brings about a sustained oscillatory condition, which will continue until something occurs to disturb the equilibrium of adjustment thus established. The operation is quite analogous to the [fol. 2540] well-known whistling phenomena which occurs when a telephone receiver is suddenly brought close to a telephone transmitter. A sustained whistling or squealing sound will frequently be produced.

Dr. DeForest states in his affidavit that he does not know of any way of making a two-element bulb oscillate, and Mr. Stone makes a similar statement. This may easily be accounted for by assuming that they did not have in their hands when they tried to do so bulbs capable of oscillating. It should be borne in mind that, whether such bulbs have

two or three elements does not determine whether they are oscillatory or non-oscillatory. There are two-element bulbs which will oscillate, and three-element bulbs which will not oscillate, no matter what may be the circuit in which they are used. The fact that a two-element valve will oscillate has been known to me for several years, and one circuit in which it will oscillate is the ordinary oscillating circuit used with the oscillating arc, which has been known for many years—as early, in fact, as the year 1900, which is prior to the date of the Fleming patent in suit.

It is unquestionably true that three-element bulbs oscillate more readily than two-element bulbs, so far as my experience enables me to judge, and that the adjustment necessary to produce sustained oscillations is less critical in the three-element bulb.

Mr. John L. Hogan, Jr., in the course of a discussion before the Institute of Radio Engineers, March 3, 1915, said that it was a well known fact that the two-electrode evacuated bulb can be used to produce radio-frequency oscillations. As reported at page 254 of the September 1915 Proceedings of the Institute of Radio Engineers, the statement reads:

“As has been known for some time, radio frequency oscillations can be produced by a simple two-electrode evacuated bulb, but my experience has been that steadier currents may be made by the application of the singing telephone relay principle to the audion repeater.”

Q. 3. I will ask you now to demonstrate to the court the oscillating capacity of the two-element bulb.

A. I might explain the apparatus to your Honor while the adjustment is being made. The valve which is being used is the small cylindrical tube having the ordinary filament, and the cold element is a plate simply suspended above it. The circuit which is being used is clearly traceable upon the board. I produce a diagram showing it in which the hieroglyphic which I mark I is the Fleming valve represented in the diagram simply by this filament and plate. The circuit is the P N circuit which was often referred to in the prior case. The regular wireless receiving coil is indicated at the extreme left, the tuning condenser at 3, shunted across it. A stopping condenser is marked C<sup>1</sup>.

The local battery circuit is indicated at the right of the bulb and comprises a battery B2. The circuit includes a

telephone in order that the device may be used both to receive and to transmit, and an inductance coil Z which I identify on the board. Shunted across this circuit is a con- [fol. 2541] denser C<sup>2</sup> which I also identify. Identifying the other elements, the coil 2 is at the left, the condenser 3 is just adjacent to it, the transmitting key which will be used to send the signals is shunted across a part of the inductance. That is a common way of transmitting the signals, and it has the effect of changing the period of the oscillations. The adjustment for temperature is by a rheostat here. The stopping condenser is here. This coil is the coil Z, and this is a coil with a single layer wound upon an iron core, the telephones connecting to the circuit as shown in the diagram.

The receiving apparatus is an ordinary receiving set containing the usual coils and condensers, and so forth, of such a set, and is arranged with all the necessary means for causing a three-element bulb, seen at the right, to oscillate and act as a detector. Similarly shunted across the coil of this is a key so that this may be used as a transmitter, and telephones are provided in the circuit so that it may be used as a receiver. Several batteries for the local circuits are seen on the back of the board. I produce a diagram which shows the circuits diagrammatically of the receiving apparatus, located on the right of the table.

Mr. Bull: The diagram is offered in evidence, the diagram of the transmitting.

Marked Plaintiff's Exhibit 2.

I also offer in evidence the diagram of the receiving outfit.

Marked Plaintiff's Exhibit 3.

A. (continued) The Fleming bulb is now being used as a transmitter, and Mr. Weagant is working the key which in practice would determine the sending of signals.

The Court: The court notes a high musical note with a kind of whistling sound.

Mr. Darby, Sr.: May I ask the court to note that in the operation of the apparatus a distinct blue glow appears in the Fleming valve between the filament and the plate?

The Court: Yes, I see that.

By Mr. Bull:

Q. 4. Will you explain what it is that indicates that the two-element valve is acting as a generator of wireless waves?

A. The Fleming valve at the left is being used as a generator of continuous oscillations, the frequency of which was changed by the operation of the key. The instrument at the right is being used as an ordinary heterodyne receiving apparatus, and the operation of the key acts to so change the frequency of oscillations due to the valve, as to bring it within the heterodyne range of the receiving bulb. The heterodyne principle is briefly this: if a set of oscillations are receiving as wireless waves, they cannot be heard in a telephone. If, however, a local source of oscillations is set up and its frequency is so adjusted that there shall be a difference between the two rates, which is an audible rate, then what are called beats will be produced and the audion which is being used as a receiver is oscillating at a frequency [fol. 2542] differing from that at which the Fleming valve is oscillating, which is about, I judged at the time when I heard it, from 600 to 1,000 per second. Therefore, the note which is heard is of that frequency, and when the key transmitter is not operated, no note is heard, which shows that the signal is not being sent at that time at a frequency which is capable of producing an audible tone when combined with that of the receiving valve.

Mr. Bull: I offer to make a demonstration, using the same apparatus inverted so that the three-element valve will act as the generator of continuous oscillations, and the two-element valve will act as the receiver of said oscillations.

The Court: As I view the matter at this time, there is no necessity for the test suggested by Mr. Bull. If, before the trial shall have concluded, either that or some other test seems desirable, we can revert to it.

Mr. Darby, Jr.: Before starting the cross-examination of this witness, if your Honor please, I would like permission—in the first place, may I have the privilege of cross-examining Mr. Weagant who actually operated this machine for your Honor? In connection with the operation of the machine, and when I reach that part of the cross-examination I will have another request, that is, I would like to request permission to operate the device myself if Mr. Waterman and Mr. Weagant have no objection.

Mr. Bull: As to cross-examining Mr. Weagant, I was only going to put one witness on the stand, Mr. Waterman. Mr. Weagant also filed an affidavit simply confirming what Mr. Waterman said. We were before your Honor then on affidavits and it was necessary or desirable to have as the statement of fact more than one witness, so I examined Mr. Weagant. Now, we have demonstrated the thing. It is not a question of what Mr. Waterman says any longer; it is a question of what we have done.

The Court: I will let Mr. Darby ask, if I understand the purport of the request, Mr. Weagant what he did just now in the way of practical demonstration in the courtroom, but as long as the plaintiff has offered only one expert, I do not want to enlarge the number of experts.

Mr. Darby, Jr.: If your Honor please, this is of vital importance to the defendant in this case. Mr. Weagant has given expert testimony in this case ~~ex parte~~, and it is of vital importance that we be given the opportunity of cross-examining him, as to the statements he made under oath in those affidavits. I am perfectly willing to have Mr. Bull offer the pertinent part of Mr. Weagant's testimony so far as the oscillation is concerned in the affidavits he has already made in the case, and allow me to cross examine him on those affidavits. It will not be necessary for him to read it for the purposes of this record.

The Court: You have got your point, I do not know what it is, but we are in this situation. The plaintiff offers an expert. Mr. Weagant has not been offered. At this stage of the [fol. 2543] proceeding I cannot read the affidavit of Mr. Weagant on the motion for the injunction.

Mr. Darby, Jr.: Mr. Waterman has read into the record his affidavits, not only in connection with what he said, but with tests that he and Mr. Weagant conducted. Now, Mr. Weagant ~~was~~ as much a party to that as Mr. Waterman was, and all I ask is the privilege of accepting Mr. Weagant's testimony under affidavit, and allow me the opportunity of cross examining him in so far as Mr. Waterman's and Mr. Weagant's testimony are linked with each other.

Mr. Bull: My friend overlooks the fact that I am captain of the plaintiff's case.

Mr. Darby, Jr.: I do not overlook it. Mr. Waterman has brought in Mr. Weagant in his affidavit, referring to the tests that Mr. Waterman and Mr. Weagant made.

Mr. Bull: Perfectly true; if you want to put Mr. Weagant on the stand as your witness you can do it, but I do not think you can put him on the stand as my witness if I do not choose to call him.

The Court: I will tell you what I think will be the orderly thing. Mr. Weagant can be placed on the stand and submitted for cross examination in regard to the physical facts as to the tests made this morning; that is to say, you may ask him how he used this instrumentality or whatever occurred this morning. Now, in so far as anything beyond that goes, if the plaintiff does not call him, you have the right to call him, but then you call him as your own witness. Of course, you are entitled in the circumstances to latitude on cross examination, as he is not your witness, but beyond the point where the cross examination ceases as to the physical procedure this morning in making the tests for the information of the court,—

Mr. Darby, Jr.: Then I will assume that the affidavit of Mr. Weagant is completely abandoned so far as this case is concerned.

The Court: It is not before me. As my opinion indicated, and as counsel followed out, this is the trial of an equity suit on bill and answer, and what has gone heretofore so far as the affidavits are concerned in respect of the motion, all of that has passed away.

Mr. Darby, Jr.: Is there any objection to Mr. Stone and myself, before we start in the cross examination of this witness, operating the apparatus ourselves?

Mr. Bull: No.

Cross-examination.

By Mr. Darby, Jr.:

X Q. 5. You are financially interested in the Marconi Company, if I am not mistaken?

A. Not in the slightest degree. I do not and never did own a share of stock.

X Q. 6. Or any of the Marconi interests?

A. No.

X Q. 7. Were you not one of the incorporators of the Pan-American Company, I think it is called?

[fol. 2544] A. I believe I am a director in the Pan-American Company at the request of Mr. Nally, but if I own a share of stock, I have never seen it.

X Q. 8. That company, however, is owned and controlled by the Marconi Company?

A. I do not even know that.

X Q. 9. You spoke in your testimony, Mr. Waterman, of the oscillion being a mere reversal of function from a detector; is that correct?

A. Yes.

X Q. 10. By that you mean that it can operate either way; that is what you would consider a fair example of the phenomenon of reversal?

A. I do not know what you imply by the word fair; it is a reversal.

X Q. 11. I will put it a different way. Take an electric motor, you put current on one side and you get mechanical energy on the other side?

A. Yes.

X Q. 12. If you put mechanical energy on that one side you get current on the other side; that is a true example of the reversal function?

A. Under proper conditions that is true, yes.

X Q. 13. You do not have to change anything as far as the motor is concerned, do you?

A. It depends on the circumstances; it depends what the motor is; it depends on all the circumstances of the case. You can arrange it so that you do not have to change anything.

X Q. 14. You can arrange it?

A. Yes.

X Q. 15. That is not so in the case of the oscillion, is it?

A. Yes.

X Q. 16. It is, for transmitting purposes?

A. I did not understand the question was limited to transmitting purposes.

X Q. 17. In other words, you can take the audion as connected in the P N circuit, and either have it receive oscillations, or to generate oscillations?

A. Yes.

X Q. 18. Without any changes whatever?

A. I have done it.

X Q. 19. Without any changes whatever?

A. Yes.

X Q. 20. Used exactly the same batteries, the same strength of currents, you have done that?

A. I do not mean to say without the adjustment of circuit, without any change of circuit.

X Q. 21. You did not have to put in any additional apparatus?

A. No; it is not usual to find a bulb that will do that, but I have done it.

X Q. 22. In fact, it is very unusual?

A. Yes, because ordinarily the valve itself does not furnish coupling enough. When you work under those circumstances the only coupling which you have between the circuits is that furnished by the valve itself. Now, in most valves that is not enough; they do not oscillate readily enough, but I have done it. I would not say that you would find one per cent. of the valves that would do it; you would have to put something in to increase that coupling. The reason for that is this, that in the three-element bulb, one circuit is connected to the filament, and to the grid, and the other to the plate and to the filament. Therefore, the only coupling, the only common part of the circuit, is the space between the grid and the filament.

[fol. 2545] Now, with the two-element valve that is not so because using the same P N circuit, both circuits are connected between the plate and the filament. Therefore you have coupling enough from the bulb itself usually. But with the three-element valve you usually do not have coupling enough, but in certain valves they oscillate perfectly well in the regular P N circuit. Now, ordinarily, you want a coupling, and that coupling may be done either by including the telephones in the common circuit, or by a small coil in the circuit, into the B battery circuit which is put where it is influenced by the grid circuit coil. Any means, in other words, that will carry energy enough over from one circuit to the other is all that is needed.

By the Court:

X Q. 23. Of course, the valves, as has been demonstrated by the cases, vary greatly?

A. Yes, sir; the individual characteristics.

X Q. 24. And the reason for that has never really been ascertained?

A. Not to rationalize it.

By Mr. Darby, Jr.:

X Q. 25. I believe the figures you used were about one per cent, if that high, of the valves could be used in a reversible manner.

The Court: Without coupling, you mean?

A. Yes; without special coupling.

By Mr. Darby, Jr.:

X Q. 26. Without changing the circuit?

A. It is not a change of circuit, Mr. Darby; it is merely changing the relation of the circuits, increasing the tightness of coupling.

X Q. 27. You are adding something which you did not have before.

A. Yes, sir, you are adding the element of coupling.

X Q. 28. That in fact is what you have done in this sketch for transmission, is it not; you have added a coupling there?

A. The three-electrode valve, yes.

X Q. 29. You have added a coupling there?

A. In the receiving arrangement there is a coupling between the two circuits which is indicated by the coils in the two which are related.

X Q. 30. And it is by means of that coupling that you can use that same arrangement for transmission in the test that was offered to be made?

A. Yes. I assume that is the case with that valve; I do not know whether it is or not; I never tried it.

X Q. 31. You have referred, Mr. Waterman, to a statement by Mr. John L. Hogan, supporting your views in connection with the testimony you have given. This statement by Mr. Hogan, as I recall, was after this original suit was filed, was it not; I think the exact date is March 3, 1915.

A. I do not know; if you say it is I will accept it.

Mr. Darby, Jr.: I believe it is the fact; the bill was filed the latter part of 1914.

The Court: Whatever the fact is.

Mr. Betts: We will concede whatever the facts are.

[fol. 2546] X Q. 32. Mr. Hogan was one of the witnesses for the plaintiff in the original hearing; I believe that is a fact too.

Mr. Bull: I note the bill was filed October, 1914.

A. My recollection is he was called, yes; he was called to testify about the hot wire barometer of Professor Fessenden which it had been said was an incandescent lamp and Mr. Hogan was called to say whether or not it was.

X Q. 33. Referring to this circuit in the transmitting circuit, where the inductance is shunted by a condenser, in the P N circuit, for example; I believe both you and Mr. Weagant hotly contested the statement of Mr. Pickard that that was an oscillatory circuit, and in the tests which you made March 6, 1916, you gave some very heated testimony about that point with the result that upon mutual consent some of the testimony was stricken from the record.

Mr. Bull: I object to that.

A. You seem to be designating one diagram and talking about another.

Mr. Bull: I ask for a ruling on that question.

Mr. Darby, Jr.: I will come back to that again.

X Q. 34. You noticed this blue glow that occurred in this circuit, Mr. Waterman, when it was acting as an oscillator, as a so-called oscillator.

A. There was a trace of blue glow.

X Q. 35. What is the explanation of that?

A. It is the incipient state of the ionization which is occurring around the edge of the plate. If that blue glow is sufficient, then it would not oscillate. That is true of both two-element and three-element bulbs. If the blue glow really comes between the elements effectively, neither one of them will oscillate.

X Q. 36. Do you know the approximate degree of oscillation of this bulb?

A. No, I do not, except that I know those bulbs were not made for this occasion. Those bulbs are simply samples out of several hundred bulbs which were made many years ago by Mr. Weagant in some work in which I was associated with him, in the investigation of the characteristics of the Fleming valve, and they were all made, in that series, of that shape, and with that shape plate, and they have various spacings, and they are all made with vacuæ of the order of incandescent lamps, or better. That bulb from its behavior

I would say had a vacuum of the order of the better incandescent lamps of Fleming's time.

X Q. 37. To get back to the blue glow, it extended from the filament to the plate?

A. No; I did not say that.

Mr. Darby, Jr.: Would you mind showing that, Mr. Weagant, for the benefit of this witness. I would like to show that blue glow does extend between the plate and the filament.

(Mr. Weagant makes demonstration.)

X Q. 38. It practically fills the space between the plate and the filament?

A. I would be very glad to admit it if I could see it, but I cannot see it. That is the usual edge blue which indicates [fol. 2547] that if you could push it harder it would blow over and go out of action, and that is where most of the bulbs, both the two-element and the three-element, have to be worked, where the spacing is as great as it is in this bulb. You recognize that is a very wide spacing, but in the ordinary commercial bulbs the spacing is only a trivial fraction of that spacing.

Now, it is my fault that we have not special bulbs here. I told Mr. Weagant not to make special bulbs. I wanted to have him just take bulbs which he had made with no thought of oscillations in mind, and I went down there and helped him select it, and we went through several hundred bulbs, and I guess we found fifty that would oscillate. Some of them oscillated better than others, and there are a few of them here in court. But I told him I did not want him to make valves for this very case, and in these long space bulbs you will always find that the local battery required is high on account of the spacing, and you will always find they work best when they are approaching the blue glow such as this, always indicated by the edge glow.

X Q. 39. Have you ever made one of these bulbs oscillate when you did not have the blue glow?

A. I do not know as I looked for it as critically as you did, but I have known them to oscillate when I did not see a blue glow.

X Q. 40. Is not in fact the blue glow striking an arc between the two electrodes: when this bulb is generating os-

illations, as you say it does, have you not established an arc between the two electrodes?

A. Well, Mr. Darby, I began working with arcs in 1888, and I have not yet heard anyone define one. If you can define an arc to me I can answer your question.

X Q. 41. Will you please answer the question?

A. I do not call that an arc, nor do I call that anything which in any way resembles an arc.

X Q. 42. You say that it does not in any way resemble an arc?

A. Yes; that is my understanding of it.

X Q. 43. What would you consider to be a fair description of an arc, as a scientific man?

A. An arc is the most difficult thing that in all my experience I have run across to define. Now, I am not willing to say that I can define an arc, but I can define certain things which unquestionably are arcs, without saying that I can limit the definition. When you connect a circuit between carbon pencils in the air and separate the pencils you draw that which everyone agrees is an arc if you have a sustained current flow. Now, that arc is a passage of current through the space separating two electrodes, using as the conveyor for current the vaporized material of the terminals. That is an arc and that definition will I think pass muster anywhere as being an arc. Now, you may have an arc under another condition.

X Q. 44. I do not believe it is necessary to go any further into that; that definition that you have given I am perfectly willing to accept. An arc, according to your definition, is where due to vapor a conducting path is established between two separate terminals.

A. Due to the vapor of the electrode.

X Q. 45. Accepting that definition, have you not established an arc between the filament and the electrodes in this [fol. 2548] valve?

A. You certainly have not.

X Q. 47. You are quite positive of that?

A. I am absolutely certain about it.

X Q. 47. As a matter of fact, Mr. Waterman, are you generating the current that comes from the bulb itself between the two terminals; is that oscillating current or alternating current, or is it pulsating current?

A. I never saw its picture, but I take it to be an oscillating current, but I do not see that it makes any difference.

X Q. 48. In other words, there is very little difference between pulsating and oscillating; there is a distinction, of course.

A. No; I do not know what the distinction is unless it is one of wave form, and I do not see that wave form interests us.

X Q. 49. Then it is immaterial whether it is pulsating or oscillating so far as its operation as a generator is concerned?

A. I did not say that. I do not know what restriction you put on the words. As I interpret them I should say it was immaterial if you merely mean to raise the question whether or not there is a true sine wave form there.

X Q. 50. First you say there is practically no distinction between them and then you will not admit that there is no distinction?

A. I did not say there was no distinction; I said I did not know what the distinction was.

X Q. 51. Do you know the difference between them?

A. I do not know how you use the term.

X Q. 52. I am trying to use the term in perfectly plain English; what is the difference between a pulsating current and an oscillating current?

A. I would say that all of these bulbs necessarily give what I now understand you mean by pulsating current. None of them oscillate because none of them go through zero; in other words, we have always a battery; we have always therefore a direct current through the space. Now, when we say it oscillates we do not mean there is an alternating current.

Mr. Darby, Jr.: If your Honor please, I asked the question as to what is the difference between oscillating currents and pulsating currents-if he finds any difference.

The Court: His answer is along proper lines; I will let him continue.

A. (continued) That direct current during the oscillating process never falls to zero, so that what really is happening is that the direct current is pulsating; it is going up and down. If that is what you mean by pulsating, that the current never goes through zero, I agree most decidedly with that; that I think is universally accepted, that in none of these bulbs does the current in the plate circuit ever go through zero; the current in the high frequency circuit, however, is a real oscillating current.

X Q. 53. I understand you then that the current which is generated, to use that expression, by that valve structure, is oscillating current.

A. Of which circuit are you speaking?

X Q. 54. Of the circuit connected between the two terminals of the Fleming valve when it is used as a generator: is that pulsating according to your definition, and I think [fol. 2549] we are agreed on the definition, or is it oscillating current?

A. The current which is passing through the plate circuit is an alternating current, superposed upon the direct current. Therefore, it never goes through zero and is what I now understand you to mean by pulsating. The current in the circuit at the left in diagram Plaintiff's Exhibit 2, and which was received as a signal at the other end of the table, representing the receiving station, that is an oscillating current in that it is not superposed on a battery current.

By the Court:

X Q. 55. When you referred to the other end of the table you were referring to the device here in court on which the experiments were made?

A. Yes; I was referring to that part of it which was used as a receiving station.

By Mr. Darby, Jr.:

X Q. 56. You are in fact referring to the three-electrode arrangement for reception?

A. I am referring to the current which was received by the three-electrode arrangement; that was an oscillating current.

X Q. 57. And the current at the transmitting station between the two electrodes of the Fleming valve is a pulsating current?

A. In the same sense that it always is in those bulbs, whether two or three element, yes.

X Q. 58. In the three electrode audion is it a pulsating current or an alternating current?

A. In the battery circuit it is a pulsating current; that is, one which never goes through zero.

X Q. 59. You mean in the circuit connecting the plate electrode and the filament electrode?

A. Yes.

X Q. 60. That is what you call the battery circuit?

A. Yes.

X Q. 61. Of course, it is perfectly apparent that while this Fleming valve structure is operating as a generator, it is not operating as a detector; you agree to that?

A. That is so much a matter of definition that I hardly know what you mean. I could hardly agree to that without taking back what I said in my *prima facie* case. To me the action is essentially a detecting action.

X Q. 62. When it is generating oscillations?

A. Yes; in other words, it is the detecting action that maintains the oscillation.

X Q. 63. You could substitute for this bulb a high frequency dynamo, could you not, or an alternating current dynamo; would that still be a detector?

A. If I had it I could, and it would of course not be a detector. If I may add to that, I do not want to be misunderstood here; your present question is different from your preceding one. The preceding one involved the question whether it was acting as a detector; as after the manner or in a similar way to a detector. Your second question asked me whether it would be a detector. Now, it would not be a detector, and the bulb is not a detector, but the bulb is acting after the manner of a detector in the act of generating.

X Q. 64. That is what I was very anxious to get at; if you inserted an alternating current dynamo, it would work just as well as with this valve, would it not; that is, it would [fol. 2550] work successfully?

A. I do not know of any alternating current that would give that frequency, but if you had one it would.

X Q. 65. It would perform the same function, of course?

A. As a transmitter, yes.

X Q. 66. And a dynamo, of course, could not function as a detector?

A. But that operates for an entirely different reason.

X Q. 67. That is true; when this bulb is operating as a generator it is not operating at the same time as a rectifier, is it?

A. In the sense that it can only conduct one way, yes.

X Q. 68. In the sense that it is detecting and rectifying alternating currents, it is not acting in that manner, is it, when it is generating electrical oscillations—I do not intend to put indefinite questions to you; that is a very simple question. I think you have said already that when it is generat-

ing oscillations it is not detecting; you have said, of course, it depends upon the same function.

A. I said it is not acting as a detector.

X Q. 69. It is not acting as a combined detector and rectifier?

A. I do not know.

X Q. 70. You said it is not acting as a detector; do you not know whether it is acting as a combined detector or rectifier?

A. I do not follow your use of terms. Obviously it is not acting as a detector because it is not being used as a detector. Now, according to my understanding, similar operations are going on within it, identically similar operations are going on within it, to those that would be going on within it if it was being used as a detector. Possibly that will answer your question.

X Q. 71. Suppose I put it to you this way. Assume for the moment that my definition of the Fleming invention is a combined detector and rectifier, is this bulb when it is generating electrical oscillations acting as a combined detector and rectifier?

A. I do not know what you mean by those words. Similar sorts of actions are going on. You are utilizing the characteristic curve in both cases. I cannot pretend to know precisely what you mean by your use of the word rectifier.

X Q. 72. You have great difficulty in understanding that question; might I put it this way?

The Court: You see, there is probably a surviving controversy as to what rectifying means; that is his point, among others.

Mr. Darby, Jr.: If your Honor please, I think the question is perfectly clear. I am asking this witness to admit what is an obvious fact, and the difficulty is in having him admit it. The cause for the difficulty I cannot understand.

X Q. 73. When that bulb is acting as a generator of electrical oscillations, is it functioning as a detector and rectifier?

A. Certainly it is not functioning as a detector. When I say that I do not take back what I said on my direct examination.

X Q. 74. Of course, it is unnecessary to ask whether you are familiar with the Fleming patent.

A. I am familiar with it.

X Q. 75. May I ask if there is any part of the Fleming patent which states, or which to you as an expert in the art [fol. 2551] would instruct you that that device could be used for the generation of electrical oscillations, and if so point out any such passage.

A. Not specifically, of course.

X Q. 76. My question was if there is anything in the patent.

A. My answer is there is nothing that has any specific reference to it.

X Q. 77. Is there anything in that patent which to you as an expert in the art would instruct you or tell you that that device could be used as a generator of electrical oscillations and if so, point out the particular passage.

A. I do not think there is. I do not think that at the date of the Fleming patent I would have derived from it the understanding that that would oscillate, but after learning that detectors which are able to amplify oscillate, knowing the telephone oscillation phenomenon, knowing that this device does amplify as a matter of fact, I would have no difficulty in understanding that it must be capable of oscillating and generating.

X Q. 78. Did you not know that any two-electrode device would generate electrical oscillations as of 1905, and by device I mean a vacuum tube.

A. No; I did not know that.

X Q. 79. I will read a passage of your affidavit made in this case—I do not recall whether this particular passage is in the record.

“There are two element bulbs which will oscillate and three-element bulbs which will not oscillate, no matter what may be the circuit in which they are used. The fact that a two-element valve will oscillate has been known to me for several years, and one circuit in which it will oscillate is the ordinary oscillating circuit used with the oscillating arc, which has been known for many years—as early, in fact, as the year 1900.”

You are familiar with that?

A. I was.

X Q. 80. What is the distinction between what you referred to there and your answer to my last question?

A. I understood your last question to ask me whether I would have known in 1905 that any two-electrode vacuum

bulb would oscillate. I do not see any relation between the two myself.

The Court: You see in the testimony just referred to he said he had this knowledge for several years; in the other question he was asked as to 1905.

By the Court:

X Q. 81. This knowledge, I assume from your answer, was only acquired later than 1905?

A. That is quite right; there was the Poulsen arc.

By Mr. Darby:

X Q. 82. You did not refer to a vacuum tube there?

A. No.

X Q. 83. Have you ever heard of the Geissler tube?

A. I have.

X Q. 84. Had you heard of it in 1905?

A. Yes.

[fol. 2552] X Q. 85. Had you ever heard that Geissler tubes would generate oscillations?

A. No, sir, never.

X Q. 86. That is a two-electrode valve, is it not?

A. It has not got any electrodes.

X Q. 87. What is known as the Geissler tube has no electrode?

A. The Geissler tube does not need to have any electrodes.

X Q. 88. Have you ever seen prior to 1905 a Geissler tube?

A. Yes.

X Q. 89. With two electrodes in it?

A. I think so.

X Q. 90. But you did not know in 1905 that the Geissler tube would generate oscillations?

A. I do not know it now.

X Q. 91. You do not know it now?

A. No.

X Q. 92. You are not in a position to deny it, though?

A. No.

X Q. 93. The Geissler tube, the two-electrode tube that I referred to consists of a tube with two electrodes separated from each other, separated in substantially the same manner as the plate and filament electrodes are separated from each other, so far as the tube structure itself is concerned; is that correct?

A. I do not think your question is complete; make your question clear. If you will make it clear you are talking about a bulb there.

XQ. 94. I am referring to the Fleming bulb.

A. I never saw a Geissler tube which would at all compare with the description of your question. The Geissler tubes which I have seen are long, slender tubes having a wire sealed in at each end, and separated six, eight, ten inches, as the case may be, and they do not in any way resemble the construction of this valve, either as to the separation of the elements or as to the character of the elements.

XQ. 95. You mean they are separated a little greater distance than the filament and plate of the Fleming valve?

A. If ten, twenty, or thirty times is a little greater, yes.

XQ. 96. That would make it a great deal difficult to create electrical oscillations, would it not?

A. I do not know.

XQ. 97. If I show you a patent of 1892, a British patent to Hutin & Leblanc, No. 23,892, of 1892, stating an alternating current of high frequency produced at a central station by an interrupter of continuous current, or by a passage of the current through vacuum tubes is sent, and so forth, would you agree that it was known in 1905 that a two-electrode tube or a vacuum tube was known for the generation of the electrical oscillations?

A. I do not know.

XQ. 98. Do you agree with that statement?

A. I have not seen it.

Mr. Bull: I object to that, your Honor.

The Court: I cannot see how this is material to the controversy.

Mr. Darby, Jr.: Your Honor, it is material, in this respect. One of our positions, which is not inconsistent with other positions which we have to take in this case, is the minute the Marconi Company, or Mr. Waterman, makes this device act as a generator, they are compelled to ignore the Fleming invention, and they are coming to the point where [fol. 2553] they are doing what was done years before, known in 1892, using two electrodes separated from each other in a vessel, in a tube, and having it set up oscillations. In other words,—I can see that your Honor does not quite get the point that I have to make, I did not want to make it

at this time—the only distinction between Fleming and the prior art devices is that it uses a hot electrode, and I am prepared to show your Honor that the hot electrode has absolutely nothing to do with its operating as a generator, and as a fact it is detrimental to its operation as a generator. Secondly, I believe it is very pertinent on the question as to whether or not the oscillion is an infringement of the Fleming valve merely because it uses a hot electrode which is absolutely essential to its operation, and the Fleming valve uses a hot electrode which is absolutely a detriment to its operation.

Mr. Bull: Now that my learned friend has stated what his purpose is, it is very evident that this is absolutely not germane to anything which we are considering here. The relating of the prior art to the Fleming invention has been gone into fully and it has been finally determined, as to the prior art and its relation to the Fleming device. I understand now he is going to attack the Fleming patent.

Mr. Darby, Jr.: Absolutely, so far as the oscillion is concerned.

Mr. Bull: We are to determine the question as to whether this same Fleming device used as a generator of wireless waves is an infringement of the Fleming patent and what we are here today to do is, as I understand it, and the only thing we are expected to do, or that it is desired we should do, was to show your Honor, convince your Honor that this thing would oscillate. When we were before you before Mr. Waterman and Mr. Weagant said it would oscillate. Now, Mr. Stone and Dr. DeForest said it would not oscillate. These proceedings were started for the purpose of ascertaining which were right.

The Court: I think there are only two issues in the case in view of the previous litigation. One is whether in point of fact the Fleming valve does the generation of the oscillations which the plaintiff claims. That is the question of fact in the case. Secondly, there may be a question of law involved as to whether, taking the Fleming patent as it was written, the Fleming patent can be availed of to cover an instrumentality such as this, whose operation was not in 1905 perhaps understood or fully understood. That is the secondary question which is a question of law. That is all there is to the case. I am not going to let any opening up of the prior art at all because that is nothing but in effect—

I do not mean to say you have not the right to press the point—but it is nothing in effect other than reopening the Fleming case, *Marconi v. DeForest*, which has gone through this court and the Circuit Court of Appeals. I would have been in a position to decide the motion on the preliminary [fol. 2554] injunction if it were not for the contest of the fact in the affidavits which made it necessary for me to determine this fact, as I explained in my opinion, in orderly fashion, where demonstration could be had, and a witness or witnesses could be examined and cross examined to see whether in point of fact this thing oscillated or it did not. We did have the Hutin & Leblanc patent in some litigation, but I am going to make the issue very narrow and if I am in error you go up on a thin record, one side or the other, and if I am not in error, that is the end of it.

Mr. Darby, Sr.: But it is not the purpose to go into the prior art; the purpose is in the present case, it is only necessary, as we conceive it, to consider the prior art with reference to the bearing on the second point that your Honor makes, and that is the question of law; whether or not the Fleming patent can be construed as a grant in the light of what it contains within itself, with sufficient breadth and scope to include something which is not referred to in that patent, not described, a characteristic which is not mentioned in the remotest way.

The Court: That seems to turn solely on the question of law,—how much of a dragnet is the patent. That involves a consideration of perhaps two or three principles of the patent law, one of which is that, of course, normally a man is entitled to all of the approximate results, even though he did not foresee them. The other is how liberal shall you be with the patent which involves an understanding of what that patent represented in the way of inventive thought and advance in the art. Those are the two cardinal principles that govern here and those are the only questions of law. Now, if Hutin and Leblanc used some words in 1892 which now in 1919 somebody or other can construe in the light of after events as meaning something that nobody ever thought about, we are going to get into a wilderness.

Mr. Darby, Sr.: That is not the purpose.

The Court: I sustain the objection.

Mr. Darby, Jr.: The whole point I had in mind was this, on the second point, which we will accept and confine ourselves strictly to in this case, and I will ask your Honor is

it not pertinent to show that the use of a generator which they are seeking to carry in this dragnet, is it not pertinent to show that that is old over their particular device; is not that pertinent; it is old at the time of their patent.

Mr. Bull: We have already determined this case; that that particular device is new.

Mr. Darby, Jr.: Not as an oscillator.

The Court: I will adhere to my ruling. I am perfectly clear as to what I have in my mind; I may be wrong, but I am clear about it.

Mr. Darby, Jr.: Exception.

X Q. 99. You have noted that in 1892 the use of a two-[fol. 2555] electrode vacuum tube for the production of the generation of electrical oscillations was old?

Mr. Bull: I object to that. Objection sustained; exception.

X Q. 100. I believe you stated, Mr. Waterman, that the use of the valve as an oscillator or generator of oscillations depends upon its function as an amplifier; is that correct?

A. Yes; that is, I do not understand that a bulb which will not amplify will oscillate.

X Q. 101. You do not understand that a valve which will not amplify will oscillate?

A. Right.

X Q. 102. And I believe it is your contention that the Fleming invention further includes both amplification and oscillation?

A. I make no contention as to the invention at all; I know that Fleming bulbs will amplify and will oscillate.

X Q. 103. I believe you have given testimony that the Fleming invention is present.

Mr. Bull: I do not think he is allowed to do that.

The Court: That is not allowed.

By the Court:

Q. 104. So far as you are familiar with the art can you tell me when this oscillation feature was realized?

A. I think I first knew it in 1913, your Honor.

Q. 105. Was that the result of experiments, or what; I mean, the ascertainment of that knowledge?

A. That was the result so far as my personal knowledge is concerned, of the work of Mr. Weagant and Mr. Arm-

strong. I was personally familiar with Mr. Weagant's work, and Mr. Armstrong's work I learned of through statements made to me by Mr. Weagant.

Q. 106. Then so far as that oscillation feature is concerned what it comes down to is this, does it not, and see if I have it right; that from the time of the Fleming patent in 1905 up to 1913, the time that this knowledge came to you, there had been a constant development in the general direction of greater knowledge of the phenomenon affecting radio?

A. Yes; that is right.

Q. 107. That is to say, that while many of the reasons for certain actions were still either unknown or debatable among scientists, the fact that certain things happened had become known?

A. Yes.

Q. 108. And this oscillation feature, or the knowledge of the oscillation, came in the course of the development of facts, to the attention of yourself and presumably other men who were concerned with a study of the art?

A. That is correct. My first knowledge of the oscillation of these tubes was as to the three-element tube. Naturally, that raised the question whether the two-element tubes would also oscillate, and on trying it we found that they would.

Q. 109. So that, putting it in another way, when this fact of oscillation became known then you endeavored to find out whether the Fleming valve would oscillate?

A. That is exactly what happened.

[fol. 2556] By Mr. Darby, Jr.:

X Q. 110. You say in 1913 you became familiar with the fact that the three-electrode valve would oscillate. You are quite sure of your date as to that?

A. No; I have not looked it up. I do not know that I could fix it. I only fix it by my recollection as probably 1913.

By the Court:

Q. 111. I suppose you are not able to definitely state 1913; it may be 1914?

A. It may be 1914, but from other events my impression is it is in 1913.

Q. 112. It is not important except as indicating that a period of years had passed from the time of the Fleming patent until this realization came about.

A. Yes.

By Mr. Darby, Jr.:

X Q. 113. Did you assist Mr. Weagant in these tests in finding that the three electrode devices would oscillate?

A. No. Mr. Weagant was engaged in the work—it is his custom to work both night and day—and he worked day-times, and I living only a few miles away from him very frequently ran down by automobile and worked with him at night and he showed me the phenomenon, as I remember it, after having discovered it himself. I remember he showed it to me as to both the three and the two-element bulbs, but my recollection is that he showed it to me as to the three-element bulb first, and later we received signals, transatlantic signals, with the two-element bulb, acting as an oscillating heterodyne machine.

By the Court:

Q. 114. Will you state on the record in a sort of summary way what difference if any there is between the physical installation in the court room now and the physical installation under the Fleming patent?

A. In the first place, the circuit which is used in the physical installation as affecting the Fleming valve in this court is the P N circuit, and not the other circuit, although I have more usually used and seen used the other circuit, that is the literal circuit of the Fleming patent.

The difference in precise detail between a P N circuit as here used and the P N circuit as was before your Honor in the exhibit DeForest box which was in evidence, is the addition of the coil Z which was not involved in that. That coil Z has the effect of adding to the apparent inductance of the telephone, and that is what it is there for, and the reason that it is desirable to add to the inductance of the telephone is that it gives a greater energy storage, and in order to supply energy rapidly as demanded by the bulbs, some storage is desirable, although it is not absolutely essential. Then, of course, the transmitting key is an additional feature.

Mr. Darby, Jr.: I was trying as far as possible to keep the testimony concerning this particular apparatus separate from the rest. I intended to cross examine on that particular point, and there are several questions I want to ask Mr. Waterman in connection with this circuit which I will defer for just a minute.

By Mr. Darby, Jr.:

XQ. 115. You said a few minutes ago that you became familiar with the Fleming valve as an oscillator quite recently; that is, fairly recently, subsequent to 1913 or 1914.

A. About that time.

XQ. 116. After Mr. Weagant had demonstrated to you that the three-electrode valve would oscillate?

A. I think it occurred in that order.

XQ. 117. When did you first have knowledge of the Fleming valve as a detector for wireless?

A. I could not say.

XQ. 118. You do not recall, you mean?

A. I think probably not very far from the time when Fleming first announced it.

XQ. 119. You were familiar with the Fleming patent about the time it was issued, or shortly afterwards?

A. No; I had no interest of an especial nature in wireless telegraphy until about 1911, as I remember, or 1910. My interests prior to that time was merely that of keeping ordinarily well informed in scientific matters.

XQ. 120. When did you first know of the Fleming patent as a patent?

A. I should say it was not so very long before the institution of this suit of which this is a continuation.

XQ. 121. You did not know that the Fleming patent was in existence until just a short time before this suit?

A. I should not say more than a year or so before that; possibly two years.

XQ. 122. Of course, you were not familiar with the use of the Fleming valve as a detector in 1905 then, if you did not know of the patent?

A. Not from any personal knowledge of it; I knew of its existence and use by others as a detector, but I had no experience with it.

XQ. 123. In 1905?

A. I would not say that.

XQ. 124. Around that time?

A. I first read about it in a paper I think published by Fleming in the ordinary course of scientific reading.

XQ. 125. You did not use one of them yourself as a detector until subsequent to 1911?

A. That is correct.

XQ. 126. I would like to read a statement, bearing in mind your answer to a question a little while ago, to the effect that an oscillator must necessarily be an amplifier. I am reading from a statement made by counsel for Dr. Fleming himself, the patentee, in the British case in which the corresponding British patent was involved.

Mr. Bull: I object to that as immaterial.

Mr. Darby Jr.: Dr. Fleming himself was a party to this proceeding and appeared personally in court, and the statement that I will read from is the statement made by his leading counsel.

The Court: How is that material? Suppose that leading counsel got up and said that Fleming did not invent anything at all. Such a statement cannot bind the people [fol. 2558] who own the patent. They take the patent for what it is worth, and the development of patent cases has indicated that time and again there is a misapprehension; either sometimes too much is attributed to the patent, sometimes too little. Statements of that kind are not in any sense germane.

Mr. Darby, Jr.: It goes further than that; it goes into the invention.

The Court: It cannot; Mr. Fessenden in *Kintner v. The Atlantic*, endeavored to disown his own child but without success; I mean, with success but not on that ground.

Mr. Darby, Jr.: The Marconi Company of England which is a stockholder of the Marconi Company of America were vitally interested. But the point is this; they have a suit in the United States on one ground and in England on another ground. To substantiate both suits they have got to take absolutely opposite positions.

The Court: That does not make any difference, either.

Mr. Darby, Jr.: They produce the man who originally drew the Fleming patent.

The Court: I will sustain the objection on the ground that it is utterly immaterial.

Mr. Darby, Jr.: Exception.

Mr. Darby, Sr.: In order to make the record clear, the offer is to read extracts from the record in the high court of justice, Chancery Division, London, England, trial before Justice Sargent in the matter of Fleming Patent No. 24,850 of 1904, and in the matter of the Patents and Designs Act of 1907, petition for prolongation; excerpts from the transcript of record of Mr. J. Hunter Gray, K. C. as counsel for the petitioners, the Marconi Company, and Professor Fleming.

The Court: That is the defendant Marconi Company?

Mr. Darby, Sr.: Yes, and Professor Fleming, the patentee of the patent in suit, and also extracts from the testimony given by witnesses called in behalf of the petitioners in that case, and also from the judgment of the court entered in the case.

The Court: What date is that?

Mr. Darby, Jr.: It started the 4th day of December, 1918, and lasted nine days.

The Court: As I understand it, there are some statements of counsel and witnesses exhibiting their views as to the scope of the patent.

Mr. Darby, Jr.: And the invention itself.

The Court: And the invention itself, in a litigation between entirely different parties from those that are here present.

Mr. Darby, Sr.: But involving the same subject matter.

The Court: Yes; involving the same subject matter. I will sustain the objection as far as the testimony is concerned. Of course, it is always permissible by way of argument in briefs to present the judgment of any court on the same subject matter.

[fol. 2559] By Mr. Darby, Jr.:

X Q. 127. Mr. Waterman, will you please explain why you have used an oscillating audion in this demonstration?

A. I do not know of any other way of receiving the undamped oscillations that I could conveniently bring to court.

(After recess.)

X Q. 128. The blue glow effect which was noticed in this bulb is due to the amount of voltage which was used to cause the device to generate electrical oscillations; that is correct, is it not?

A. Yes; the voltage in the plate circuit.

X Q. 129. Would the two-electrode Fleming valve device using a battery current of sufficient potential to cause the blue glow to appear, operate effectively as a detector for radio purposes?

A. Yes; in the condition in which the bulb was seen this morning, it will neither oscillate nor detect if the blue glow is too pronounced. The blue glow is a pure incident to certain valves; that particular one happens to work at that point on the characteristic curve; that is all.

X Q. 130. If you were to use this valve for detecting purposes you would not use the same amount of voltage in the circuit as you would use when it is connected for generation purposes, would you?

A. I think so, yes.

X Q. 131. You would use the same amount of voltage?

A. Yes.

X Q. 132. What is the amount *for* voltage that is employed in the oscillating circuit of the Fleming two-electrode device as demonstrated by this apparatus?

A. I did not notice that; I can ascertain it.

Mr. Bull: You can ascertain by having Mr. Weagant tell it.

X Q. 133. In using this device, and I refer to the Fleming two-electrode device for detection purposes, what is the amount of voltage that you employed in the circuit?

A. It depends upon the individual valve and upon what particular part of the characteristic curve you are working on.

X Q. 134. What is the maximum voltage which you have ever used for that purpose?

A. In valves of that construction, I should say around 100 volts; maybe 200; I cannot say to a certainty.

X Q. 135. I am asking you what is the maximum voltage which you have ever employed in connection with a two-electrode valve for detection purposes?

A. That is what I was answering to. In my own station, I customarily have only about 100 volts and I have used about all of that, I am sure, but when I have been working with Mr. Weagant he had higher voltages, and I do not know whether he used them or not on these particular tubes. I should think these tubes the voltage ran between 25 and 100.

X Q. 136. What is the normal voltage that is used in the actual commercial use of this detector?

A. Are you speaking of valves of this particular type?  
[fol. 2560] X Q. 137. Any two-electrode type.

A. Well, they have often been used with no voltage at all.

X Q. 138. For detection purposes?

A. I think in the customary commercial use that I have been familiar with it is between zero and twelve volts. These bulbs, however, have a greater separation between filament and plate, and therefore take a higher voltage.

By Mr. Bull:

Q. 139. You mean the bulb?

A. I mean the bulb of which the individual here in court is a sample.

By Mr. Darby, Jr.:

X Q. 140. You have witnessed, of course, the two-electrode bulb used for detection purposes commercially, have you?

A. Yes.

X Q. 141. In that particular instance, do you recall what the voltage was?

A. No; I do not.

X Q. 142. You could not limit it; you could not come within limits of which you feel certain it was used?

A. The limit of the total storage battery I believe was 12 volts.

X Q. 143. You have stated in your testimony that the Fleming two-electrode device if properly constructed—I think those are the exact words you used—will oscillate; that is correct?

A. Yes.

X Q. 144. Do you find any information in the Fleming Patent as to instructions as to how to properly construct the Fleming valve device to cause it to generate oscillations?

A. Yes.

X Q. 145. Will you refer to the particular passage please that tells you what the proper construction is?

A. Well, at page 1, line 71.

X Q. 146. Will you please read it?

A. It says, "I generally heat the carbon filament to a high state of incandescence by a continuous electric current." That is one of the essentials.

X Q. 147. Before we go to the next essential, will you please tell me what is contained in that statement which tells you how to properly construct the Fleming valve structure to cause it to generate electrical oscillations.

A. It is only a matter of so proportioning the filament that with the battery to be used the filament will heat to a bright incandescence.

X Q. 148. Then, as I understand you, before we get to the next point, that the only proper construction of the bulb is the amount of current that you have got to supply to the filament?

A. I said that is one feature.

X Q. 149. Am I correct that what you had in mind was not the proper construction of the bulb but the amount of current that is used for the filament; is that correct?

A. That is a matter of construction of the bulb in the ordinary sense. If you are constructing to meet a certain set of conditions you must so construct your filament that it can be brought to a very high state of incandescence. That is one of the necessary conditions. I was going to refer to another.

X Q. 150. But pardon me, I just want to clear these different points up as you raise them. In your testimony where you said that a bulb properly constructed, you mean [fol. 2561] that all you have got to do is to supply more current to the filament of the structure?

A. I did not say that.

X Q. 151. That is what I am trying to get at; just exactly what do you mean by your expression?

A. That is not what I said; I was going on to tell you the rest.

By the Court:

Q. 152. Suppose you then give all of the elements.

A. Then he says at various places, as for example, page 1, line 96.

"As a very high vacuum could be obtained in the bulb and as a considerable quantity of air, and so forth——"

The two conditions are that you should be able to heat the filament to a high temperature and that you should have a high vacuum in the bulb. Now, it is true that not all bulbs, so far as I know, which have a high vacuum, and which can have the filament heated to a high temperature within the

limits of the apparatus, will oscillate, and what the critical condition that makes them oscillate is I do not know. It is a matter of the characteristic curve as to which we have comparatively little control, but by "properly constructed" I think I said in my examination exactly what I meant, namely, provided it had high enough vacuum. What I said was that all the Fleming valve bulbs, including the so-called three-element audion, exhibited before the court, have the property of "oscillating" when properly constructed—that is, if they are provided with a sufficiently high vacuum.

Q. 153. Then the only proper construction which you would require would be a sufficiently high vacuum in the bulb, to which you have added now the condition of supplying more current to the filament?

A. Yes. In other words, what I meant to say was that no special or different conditions are imposed than that imposed in constructing the bulb as a detector.

Q. 154. Let me ask you this; the higher the vacuum you have in this tube the poorer the tube will act as a generator of oscillations; is that correct?

A. I do not know.

By Mr. Darby, Jr.:

XQ. 155. I will now ask you a few questions in connection with the circuits employed along the lines of the questions asked by his Honor. It is so obvious that I do not believe it is necessary to emphasize it. The circuit employed in connection with the Fleming valve as a generator is nowhere disclosed in the Fleming patent.

A. I will be glad to operate it in that circuit if you would like.

XQ. 156. The fact that it will operate in connection with this circuit for the generation of electrical oscillations is something that has developed in the art subsequent to the Fleming invention.

The Court: That is in the circuit shown on Plaintiff's Exhibit 2.

A. The fact that it will oscillate at all, so far as I am personally concerned, is something that has been developed in [fol. 2562] comparatively recent years. That circuit is the P N circuit, and it is the circuit which is Fig. 1 of the Marconi Patent No. 627,650, I believe, which I showed in the

main case. I showed in that case that there were in that patent two circuits shown, one of which is the circuit shown in the Fleming patent and the other of which is the circuit that happened to be used with the DeForest audion box which was the subject of that litigation, and this circuit here is that circuit of the audion box but which is known as the P N circuit.

Re direct examination.

By Mr. Bull:

RDQ. 157. Will you please explain how the oscillating function of the incandescent lamp detector was discovered, so far as you know?

Mr. Darby, Jr.: If your Honor please, on that point I believe that Mr. Waterman has already testified that Mr. Weagant was the one who discovered it. Mr. Weagant is available to Mr. Bull if he cares to examine him on that point. This is secondary evidence.

The Court: He may answer.

A. The matter first came to my attention in my own use of the three-element bulbs. I was using them as detectors for the receipt of ordinary damped oscillation signals, including for example the station at Sayville, and that was the longest wave length station which my apparatus was able to receive, and I had one valve which I noticed, a three-element valve which I noticed would on a certain adjustment of the secondary condenser give a thump and immediately upon giving that thump the bulb became more sensitive and the signal came with a broken or raspy note, whereas it was characteristically a clear and musical note.

RDQ. 158. You mean the Sayville note was a clear note?

A. Yes, and I endeavored for many weeks, or over a period of time covering many weeks, to try and get the same sensitiveness without getting that peculiar note, but without success. Some time later when I was working with Mr. Weagant he explained to me that the three-element bulb was capable of acting as an oscillator and he tuned his circuits to a longer wave length than I was able to reach and immediately there came in a clear and musical signal which was the signal from an undamped oscillation station and I then recognized that what had happened was that the audion which I was using had begun to oscillate, and it was

in the use of the bulb as a detector in that way that the matter first came to my knowledge, and so far as I know also to Mr. Weagant and Mr. Armstrong.

RDQ. 159. You mean, you recognized the fact that when you got this loud and disagreeable note it was due to the fact the bulb was oscillating?

A. Yes. It is characteristic, I ought to explain, that when a damped oscillation is received with the bulb in the oscillating state, the musical note which is transmitted and which that signal would have if received by a crystal, or by a bulb in the non-oscillating setting, is changed from the [fol. 2563] pure musical note to a tone which has an aspirated sound, a whispering sound; it is broken up and ceases to be clear and musical.

When, on the other hand, a continuous wave or undamped oscillation is received by the beat method, then it is a characteristic of the oscillating valve that it gives a clear musical note. The musical note, for example, that your Honor listened to this morning is the note which is characteristic of a beat note due to the superposition of the oscillations of a different frequency, and the reason it is purely musical is because both giving continuous oscillations which differ by a definite amount, the beats are in effect sinusoidal; that is, simple harmonic, as it is called, and therefore makes a pure tone. Probably the nearest to a pure musical note of a signal that it is possible to produce in any way.

Now, when a damped oscillation is received there is no such adjustment. The valves may be oscillating, for example, at a frequency five or ten times that of the signal. Therefore, we do not have any beat effect produced, but we are merely using the valve in its ordinary way of detector plus the extra sensitiveness that comes from the oscillating condition, and so when you receive a damped oscillation one gets usually this ragged sound when the bulb is oscillating and recognizes the oscillation in that way, whereas, to receive the undamped or continuous oscillation, the beat effect has to be produced and that results in the pure musical note. And when I had my audion valve, it was a DeForest bulb, oscillate, before I knew its capacity for oscillating, it was giving this raspy note, although I did not at that time recognize it as the oscillating state and was using it as a detector, and noticed this happening, but I had not the capacity to adjust to the long wave length stations of the continuous oscillations and therefore I never myself proved

it was oscillating; Mr. Weagant did that by his ability to tune to the wave length of the continuous oscillation stations which was very long.

Of course, when it is once recognized that the bulb is oscillating, it is perfectly evident that it may be used either for heterodyne reception or as a source of oscillations for some other purpose.

RDQ. 160. Speaking from your general knowledge of the art, your expert knowledge of this art, is it or is it not true that the oscillating capacity of these incandescent lamp detectors was discovered in connection with, and directly in connection with a use as detectors of wireless waves?

A. That is the fact so far as I know, and as has always been stated and understood.

RDQ. 161. And when it was ascertained that one of these valves had the capacity for oscillating, was it or was it not obvious to one skilled in the art that that valve could be used as a generator of wireless waves?

Mr. Darby, Jr.: I object to that. Objection sustained.

RDQ. 162. Have Geissler tubes ever been used in the radio art for any purpose so far as you know, either a detector or generator or anything else?

A. They have not, with the single exception that when without electrodes they have been used in experimental work to indicate nodes of wires and the like.

[fol. 2564] RDQ. 163. But not for the purpose of receiving radio signals or generating radio waves?

A. They have not so far as I know.

Re-cross-examination.

By Mr. Darby, Jr.:

RXQ. 164. In this work in which you discovered the oscillating characteristic of these vacuum tubes you were working with a three-electrode audion?

A. Yes.

RXQ. 165. And as you have previously testified, that was around 1913 or 1914?

A. That was earlier, it was before I learned from Mr. Weagant about the capacity of the valve to oscillate. I noticed this peculiar behavior and I did not know what it was, but I identified it afterwards.

RXQ. 166. In your work with the Fleming two-electrode valve prior to this discovery of oscillations with the three-electrode device you did not discover any oscillating characteristic of the two-electrode device, did you?

A. No.

RXQ. 167. In fact, the discovery of the oscillation characteristic of the two-electrode device was subsequent to your discovery and explanation by Mr. Weagant of the three-electrode device.

A. Mr. Weagant made it and my understanding is that that was the succession; it was the order in which it was revealed to me, at any rate.

RXQ. 168. It was your understanding, referring to the question asked you by Mr. Bull, that Mr. Weagant made this discovery while using the audion as a detector; is that correct?

A. Yes; all his work at that time I was familiar with was detector work; in fact, if he did not know it would oscillate he could hardly have been using it as a generator.

RXQ. 169. And as you say that was somewhere around 1914 that Mr. Weagant, or the latter part of 1913, that Mr. Weagant when using it as a detector discovered that the three-electrode valve would oscillate?

A. I said to the best of my recollection it was 1913.

RXQ. 170. Could you construct a two-electrode valve that you know would generate electrical oscillations, and by two-electrode valve I mean a two-electrode valve of the structure shown by Professor Fleming?

A. If you mean if I could construct a single valve and guarantee that it would oscillate, I do not think I could. But, of course, I personally am not skilled in the construction of those things. I never built one in my life.

RXQ. 171. In other words, you never know whether a Fleming valve structure, two electrodes, will generate oscillations until you try?

A. Well, that is not peculiar to the matter of generating oscillations. The valves are very hard to control. It is not possible in advance to tell precisely what they are going to do, whether it be acting as a detector or as a generator.

RXQ. 172. At any rate, you agree to this, that not every Fleming two-electrode structure which will act as a detector will act as an oscillator?

A. That is true as to the few that will not act to amplify; if they will amplify they will oscillate.

By Mr. Bull:

Q. 173. Let me ask you this; when one of these incandescent lamp detectors is being used as a detector of wireless waves, and it is in the oscillating condition, is it true that that valve at that time is acting as a generator of wireless waves?

A. It is, absolutely.

Q. 174. And as to some two-element bulbs acting as generators and others not, is the same thing true of the three-element valves?

A. So far as I know, it is; that has always been my observation.

By Mr. Darby, Jr.:

R. X Q. 175. You do not know definitely, though, do you?

A. I would not say that I do, No.

By Mr. Bull:

Q. 176. Did you ever have a three-element valve that would not oscillate?

A. Yes; I have got some now.

Q. 177. Then you do know definitely?

A. I understood Mr. Darby to ask whether one could be constructed with a certainty that it would oscillate.

By the Court:

Q. 178. Mr. Bull's question was whether you would find instances of failure to oscillate in three-electrode valves just as well as in two-electrode valves.

A. There is no question about that. I have at least two made by the DeForest Company that cannot be forced into oscillations and I know that in some of those that were in evidence in this case I tried very hard to make them oscillate and did not succeed.

Q. 179. You mean in the same case?

A. I mean in the same case. There were several in the case and they were all alike; some of them oscillated and some of them did not under my manipulation; I do not know what anybody else might be able to do.

By Mr. Darby, Jr.:

R. X Q. 180. In those valves which would not oscillate, did you try them to see whether they would detect?

A. Oh, yes; they detected but they would not amplify.

Mr. Darby, Jr.: I would like to ask Mr. Weagant a question in connection with this apparatus which Mr. Waterman was not in position to answer.

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ROY A. WEAGANT, a witness called on behalf of the defendant, being duly sworn, testifies as follows:

Direct examination by Mr. Darby, Jr.:

Q. 1. Mr. Weagant, do you know the amount of voltage that is employed in the oscillating circuit of the Fleming valve structure in this apparatus?

A. I think it is approximately 100 volts; I can have it measured right off, if you would like it.

Q. 2. I would like it. (Witness measures apparatus.)

A. The voltmeter shows 96 volts.

[fol. 2566] Q. 3. Are you familiar with the use of the Fleming valve structure, of the two-electrode structure, used for detection?

Mr. Bull: I object to that. I am going to try and confine this witness's examination to the condition of this apparatus and the manipulation of it and anything of that sort.

The Court: Objection sustained unless you call him as your own witness.

Mr. Darby, Jr.: I will make Mr. Weagant my own witness for the purposes of this question.

The Court: You better call him in your case.

Plaintiff's prima facie case closed.

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#### Defendant's Proofs

ROY A. WEAGANT, recalled in behalf of the defendant, testifies as follows:

Direct examination by Mr. Darby, Jr.:

Q. 4. Are you familiar with the use of a two-electrode Fleming valve for detection purposes commercially?

A. Somewhat, yes.

Q. 5. When did you first become familiar with it for detection purposes in commercial use?

A. I do not know that I remember exactly.

Q. 6. Can you give me the approximate time?

A. It was at least earlier than 1912.

Q. 7. You cannot be more definite than that?

A. No; I do not know that I can; I do not remember particularly.

Q. 8. You do not know whether it was one or two or five years earlier than that?

A. No; I really do not.

Q. 9. Was it as much as two years?

A. I cannot say definitely because I am not sure; it may have been.

Q. 10. That is your best recollection then?

A. That is my best recollection, yes.

Q. 11. What voltage was normally used and was used in connection with the circuit of the two-electrode valve as used as a detector when you first became familiar with it?

A. I cannot be sure as to that, when I first became familiar with it. I recollect voltages of six, twelve, and I think occasionally eighteen and twenty-four, but I am not very certain about the latter.

Q. 12. Is it not a fact that the general and usual voltage used commercially is around twelve volts for detection purposes?

A. Are you referring now to the two-electrode valve and to any specific type?

Q. 13. Any type of two-electrode valve used commercially for detection purposes; I am, of course, referring to the Fleming valve.

A. I have seen the two-electrode valve used with so many voltages and over such a wide range that I am not sure I can answer your question definitely; voltages of six and twelve were very commonly employed.

Q. 14. They were the more common?

A. Yes; and I would say they were the more common, as far as I can recollect.

[fol. 2567] Q. 15. And I believe the record shows that the voltage that is employed here is about 96 volts?

A. That is correct.

Q. 16. When did you first discover that a two-electrode valve, Fleming structure, would generate oscillations?

A. I do not know that I can say; it is since 1913, but I do not definitely remember the exact time.

Q. 17. Your discovery of that characteristic of the two-electrode valve was subsequent to your discovery that the three-electrode audion would generate oscillations; is that correct?

A. It may have been, but I am not certain at this time.

Q. 18. You considered yourself to be the inventor or discoverer of the phenomenon that the three-electrode valve would generate oscillations, did you not?

A. I probably did.

Q. 19. In fact you filed an application for patent for it, did you not, claiming that particular feature?

A. Very likely; yes, I think I did.

Q. 20. And in that application you did not show a two-electrode valve, did you?

A. That I cannot say; I am quite hazy in my recollection of the application at that time.

Q. 21. I will ask you if this is a correct copy of the drawings of your application for patent disclosing and claiming the use of a three-electrode audion as a generator of electrical oscillations.

A. It evidently is one of my applications, yes, as near as I can judge from the figures.

Q. 22. You have never filed an application for the discovery that a two-electrode valve would generate oscillations, have you?

A. Yes.

Q. 23. A two-electrode valve alone?

A. Yes; I think so.

Q. 24. Are you referring to a structure where you use a three-electrode surrounding the tube?

A. No.

Q. 25. And the application which you refer to is completely independent of this application that I hold in my hand?

A. So far as I recollect. I am not certain on that because my recollection is not very definite.

Q. 26. In this application which was filed for you and in which you took the oath that you had invented the subject matter the following illustrates what you claim to be your invention, does it not?

"Means for generating electrical oscillations comprising a plurality of elements separated by a conducting gaseous medium."

A. I do not know that that was the language.

Mr. Bull: I object to that, your Honor. If he wants to ask him any questions of fact, well enough. He is reading evidently a claim which is the product of a patent solicitor. I do not see that that has anything to do with the case.

Mr. Darby, Jr.: We will offer in evidence a copy of the application as a physical exhibit. The claim that I have read is a claim as filed; it is not, as has been suggested by Mr. Bull, the wording of a patent attorney; it is what Mr. Weagant took the oath on as constituting part of his invention.

[fol. 2568] The Court: Counsel for the other side do not object to the receipt in evidence of this application; it may be marked.

Mr. Darby, Jr.: I offer in evidence the file wrapper of the application of Mr. Weagant, Serial No. 830,584, filed April 9, 1914, for "Means for generating electrical oscillations."

Marked Defendant's Exhibit A.

Q. 27. Now, for the purpose of fixing the time when you made this invention, may I ask you if you did not file an affidavit in that case in which you set forth the time you made the invention?

Mr. Bull: The application is in evidence.

Q. 28. Do you recall when you filed your application for the two-electrode valve as a generator?

A. No; I do not.

Q. 29. You do not know whether it was before or after this application?

A. I do not recall to a certainty, no.

Q. 30. That is your recollection?

A. I think it was after.

Cross-examination by Mr. Bull:

X Q. 31. You have been asked about the voltage commonly used with two-element valves. Does the voltage used have anything to do with the space between the incandescent element and the plate filament?

A. Yes.

X Q. 32. That is, the separation of those two elements?

A. Yes. The voltage used depends to a very great extent on the separation between the hot and the cold electrodes. In general, the greater you make that separation the greater is the voltage that will be used in the use of the valve as a detector.

X Q. 33. Is the separation of this particular valve which was demonstrated this morning greater or less than the separation which is ordinarily present in the commercial two-electrode valve?

A. It is quite a bit greater than is usual.

X Q. 34. If this particular valve were used as a straight detector would it not therefore require a higher voltage than one of the ordinary commercial two-electrode detectors?

A. In all probability it would, yes.

Re-direct Examination by Mr. Darby, Jr.:

R. D Q. 35. In using the Fleming two-electrode valve for detection purposes, you refer to the voltage as the battery A, or the voltage used for lighting the filament, do you not?

A. Not in any answers I have made so far, no.

R. D Q. 36. You have been using what has been called the B battery voltage?

A. I am referring to the voltage between the cold electrode and the hot electrode.

R. D Q. 37. In what respect does the spacing of the electrodes of the device employed for this demonstration differ from that employed using the two-electrode device for detection purposes?

A. Of necessity it does not differ at all; that same spacing is a perfectly good spacing for detecting purposes.

By Mr. Bull:

Q. 38. Were not these made for detectors, as a matter of fact?

A. Yes; they were.

[fol. 2569] By the Court:

Q. 39. As I understand from Mr. Waterman's testimony, this bulb with some other bulbs were on hand from some time ago?

A. Yes; that is correct.

Q. 40. That is to say, he selected some old bulbs for the purpose of the demonstration to the court?

A. Yes.

Mr. Darby, Jr.: I believe Mr. Waterman also said that he tried them and picked out those which would oscillate.

Mr. Bull: Yes.

JOHN STONE STONE, a witness called in behalf of the defendant, being duly sworn, testifies as follows:

Mr. Darby, Jr.: May I ask if you will concede Mr. Stone's qualifications?

Mr. Bull: I certainly will.

Direct examination:

By Mr. Darby, Jr.:

Q. 1. How long have you been familiar with vacuum tubes?

A. Since about 1892.

Q. 2. How long have you been familiar with the use of vacuum tubes with respect to high frequency work?

A. My first experience with vacuum tubes in high frequency work was some time in 1893.

Q. 3. Have you had occasion to make a thorough investigation and study of vacuum tubes in the various uses to which they may be put?

A. I have had considerable experience with vacuum tubes, the matter of detecting electrical oscillations and generating electrical oscillations.

Q. 4. And amplification?

A. Some.

Q. 5. You witnessed and took part in the demonstration of this apparatus that had been set up by the plaintiff I believe?

A. Yes.

Q. 6. You noticed the blue glow effect that took place in the Fleming two-electrode structure when it was as the plaintiff states generating electrical oscillations?

A. Yes.

Q. 7. Will you please describe in your own language what produced that blue glow, its effect on the circuit, and what

you can tell us in connection with the phenomenon of the appearance of that blue glow.

A. The blue glow is a phenomenon which takes place in a vacuum tube when the potential difference, or the electromotive force acting between the two electrodes, reaches such a high value as to produce a sudden decrease in the electrical resistance between those electrodes. I will not go into the scientific explanation of the mechanism that produces that sudden diminution of resistance, and will say that it is a very well recognized phenomenon, however, and amongst operators and the like, the character of users of audions and valves, it is generally spoken of as striking an arc. Personally I do not consider that the phenomenon is identical with the electric arc, but it is in the same nature an arc in so far as its effect upon the resistance of the space between the electrodes is concerned.

[fol. 2570] Q. 8. Might I ask when you say striking an arc in the colloquial, if you please, the interpretation of that, do you mean striking an arc between the electrodes?

A. Yes.

Q. 9. Might I ask is the function of that blue glow the same as the arc?

A. Functionally it seems to operate in much the same way as if a true arc were struck between the electrodes. It differs from a true arc between the electrodes only in that the diminution of the resistance which it establishes between those electrodes is not so great as would be the case if a true arc were struck between them.

Q. 10. What is the effect of that blue glow or arc on the two-electrode device for detection purposes?

A. As soon as the blue glow commences to appear in a rectifying valve, vacuum tube valve, its qualities as a rectifier, and therefore as a detector, begin to wane very rapidly, and as the blue glow increases until it finally reaches from one electrode to the other, the deleterious effect upon the detecting function of the valve becomes greater and greater until finally the valve becomes extremely inefficient or inoperative for detection purposes. And when I speak of this diminution of efficiency in the valve as a detector I do not refer to matters of small percentage, but the change is so great that a detector which may be receiving easily readable signals may cease to develop audible signals even, and a valve which is receiving quite loud signals may under the

influence of the blue glow become so inefficient that the signals become unreadable.

Q. 11. Is it possible to make a two-electrode device generate oscillations without striking that arc which you refer to?

A. So far as my experience goes, and theoretical investigation that I have made of the simple valve, or rectifier, I am convinced that it cannot oscillate unless the blue glow or so-called arc exists between the electrodes.

Q. 12. In other words, striking the arc which I believe is admitted causes the blue glow to appear, is absolutely essential and necessary for the two-electrode device to act as a generator of oscillations?

A. That is my opinion.

The Court: Then what follows from that?

Mr. Darby, Jr.: This follows, if your Honor please; it shows conclusively that you have to completely eliminate Fleming's invention to use it as a generator; in other words, the contention that it will detect is absolutely opposed to the contention that it will act for generation purposes. The minute that it strikes an arc, the minute that it generates oscillations, it absolutely ceases to rely upon its detection properties for operation.

Q. 13. May I ask if you are familiar with a similar blue glow effect in the three-electrode audion?

A. Yes.

Q. 14. Is the striking of the arc, or causing this blue glow effect to appear, necessary for the operation of the audion?

A. No; the presence of the blue glow or so-called arc militates greatly against the efficient operation of the three-electrode audion as a detector, and it also militates against its operation as an oscillion or oscillator.

[fol. 2571] Q. 15. Would the audion operate if the blue glow effect appears?

A. It begins to cease to operate effectively as soon as the blue glow appears.

Q. 16. That is what has been commonly known as paralyzing the audion, is it not?

A. Yes; the operators use that word.

Q. 17. And means have got to be taken to prevent the paralyzing of the audion or to immediately dissipate that condition as soon as it appears; is that correct?

A. Yes.

Q. 18. I believe I understood you to say that you personally knew that a two-electrode device would generate high frequency oscillations about 1893.

Mr. Bull: I object to that, if they are going into the prior art. I do not know whether that will anticipate our patent or not.

Mr. Darby, Jr.: I want to lead up to the point of when the discovery was made of the oscillation and generation by a three-electrode device as distinguished from a two-electrode device.

Mr. Bull: Ask him that question.

Mr. Darby, Jr.: I have asked that question; I wanted to be correct as to my starting point before proceeding.

The Court: Reframe the question.

Q. 19. Will you please explain how you discovered in 1893 that a two-electrode device would generate electrical oscillations?

The Court: I do not get this at all.

Q. 20. I will ask you this; when did you first obtain knowledge that the three-electrode device would generate electrical oscillation?

A. In 1912 I received that knowledge indirectly in this way; I received a letter from Dr. DeForest who was out on the Pacific Coast informing me that he had discovered that his audion would amplify alternating currents, whereupon as an old telephone engineer I wrote him a letter stating that if it would amplify telephone currents or any other currents, it would certainly oscillate, and pointed out to him what particular kind of circuits he would have to use in connection with his audion in order to prevent it from oscillating in case he wanted to do so in its use as a telephone amplifier, and I needed no further information than the fact that the audion would amplify to know that it would oscillate, nor would any other competent telephone engineer need to know anything more.

Q. 21. In what connection were the two electrode vacuum tubes that you were familiar with in 1893 used; that is, for what purpose were they used?

Mr. Bull: I object to that.

Mr. Darby, Jr.: If your Honor please, this is of the two-electrode device for generating high frequency electrical

oscillation. I want to prove by this witness that in 1893, two-electrode devices for the production of high frequency oscillation were known, and further than that, that the only difference between this device and what was known [fol. 2572] and used at that time for that purpose was that in Fleming they used a hot electrode, one electrode is heated, whereas in the old device one electrode was not heated. I want to further prove that so far as the operation of a generator of electrical oscillations is concerned, it makes no difference whether that electrode is heated or not, and further that the actual heating of the electrode is detrimental to its generation of electrical oscillations. I think that is wholly pertinent.

Mr. Bull: In the first place, I object to their going into the prior art. That is simply an effort to anticipate our patent, as I understand it. In the second place, I do not think I could have correctly heard what Mr. Stone said because my understanding is that we are here simply because Mr. Stone on the motion filed an affidavit in which he said you could not make a two-electrode device work and I think he is asking him if he did not make a two-electrode device generate way back in 1893.

The Court: Your argument as to certain proofs covered several points. I alone directed myself to one. I think any testimony which in effect is in the nature of anticipation of the state of the art prior to Fleming is not admissible in this case. Now, that is the theoretical side. Now, the practical side is this, that the books have now grown full of cases which show that certainly not in 1893 did any person have any conception of the power of generation and oscillation in its present relation; that is as certain as anything can be. A man might look back for all I know on some theoretical business about oscillations and all that sort of thing, but from the radio standpoint to go into the dark ages and the past ages to find out what happened in 1893 to my mind is utterly immaterial.

Now, on the question as to what the two-electrode will do and what a three-electrode will do, that is a different proposition. There Professor Stone's experience as a scientific man and an expert is entirely relevant along the questions which are intended to show how these things work and what in fact they do, and so on. I am perfectly clear from the testimony, I do not believe anybody disputes the fact,

that the oscillating properties or the characteristics were unknown in this relation to the scientific world until a considerable number of years after Fleming invention. As I said this morning, if the thing does oscillate, if the Fleming valve does generate, the next question is purely a question of law.

Mr. Darby, Jr.: If your Honor please, I ask you not to forget one point and that is that the plaintiff in this case is seeking to include the oscillating audion as an infringement of their patent, and to do so they have got to broaden the scope of their claims to enable them to do so.

The Court: That is a question of argument; that has got nothing to do with this 1893 proposition; I will sustain the objection.

Mr. Darby, Jr.: Exception.

Q. 22. Mr. Stone, is the heated electrode or hot electrode of the Fleming two-electrode device absolutely essential [fol. 2573] to its use as a rectifier?

A. Yes. I will say that the heating of the filament electrode in the Fleming valve is essential to its operation.

Q. 23. If the hot electrode of the Fleming valve is not heated; in other words, if the heating battery is omitted, and a sufficient voltage is employed, would the device generate electrical oscillations?

Mr. Bull: I object to that; I think it is utterly immaterial.

The Court: What is your theory on that?

Mr. Darby, Jr.: My theory is this; my next question which I intended to ask to bring it out, was if the filament was not heated, it would generate electrical oscillations more efficiently than if it were heated.

The Court: Suppose it did; then go and use one that is not heated.

Mr. Darby, Jr.: Then, of course, they would not have the Fleming invention there.

The Court: You have got one electrode that is heated; they have one that is heated. Now, you can use the finest kind of cold electrodes in the world and they do not care anything about it.

Mr. Darby, Jr.: Suppose in the three-electrode device, the hot electrode is absolutely essential for its work, whereas in the two-electrode device it is detrimental; does not that alter the situation, as a generator?

The Court: I will sustain the objection on the ground that the question is immaterial and irrelevant.

Mr. Darby, Jr.: Exception.

Q. 24. Will you examine those two circuits, Plaintiff's Exhibits 2 and 3; referring to the apparatus which those circuits, for the sake of convenience represent, you will note that an oscillating audion at the receiving end is employed, and you will further note that the receiving end is inductively coupled to the transmitting end; that is correct, is it not?

A. It is correct as to the apparatus of the demonstration but it is not shown in these exhibits as far as I can see.

Q. 25. You mean that the inductive coupling between the receiving and the transmitting is not shown?

A. Yes; that is what I mean.

Q. 26. In the receiving system the electrical oscillations are being generated, are they not?

A. Yes.

Q. 27. What effect would the electrical oscillations generated in the receiving system have upon whether or not the two-electrode device is actually generating electrical oscillations?

A. It is very difficult to say. The oscillations which are generated in the receiving circuit or the oscillating three-electrode audion, are in part due to the oscillation circuit of the two-electrode valve, and what effect that would have upon the oscillation of that circuit, or the maintenance of the oscillations of that circuit, is very difficult to say; it is impossible to say—*a priori*. The only way that I can imagine the effect of these oscillations to be determined would be to substitute a non-oscillation producing detector in a receiving circuit, and coupled with the interrupter, breaking [fol. 2574] up the train of continuous waves, and then see whether the two-electrode valve would oscillate in the transmitter without the coupling between the transmitter and the receiver.

Q. 28. What is the nature of the coupling between the oscillating audion system and the receiving system?

A. It is difficult to say what it is because the wires run back of the board, but I fancy it is a simple inductive coupling.

Mr. Bull: If you want any wires straightened out for you we will be glad to help you.

The Witness: I have examined it and find it is a simple inductive coupling between the transmitter and receiver as I had previously supposed.

Q. 29. What ordinarily is the effect of an inductive coupling between an oscillating circuit and another circuit?

A. Well, in the well known case of the grid plate circuit of the three-electrode audion, and the filament grid circuit, it is essential in causing the device to operate. A similar action might or might not take place here by the coupling between the plate filament circuit of the oscillating audion and the filament plate circuit of the two-electrode valve.

Q. 30. By the use of this three-electrode oscillating audion in this demonstration apparatus, coupled as shown by the apparatus itself, does it raise a doubt in your mind as to whether or not the two-electrode device is generating electrical oscillations of a degree sufficient to be detected?

A. No; it is undoubtedly generating those oscillations, but the coupling makes me doubt whether the two-electrode tube would oscillate in that circuit, except for the coupling with the oscillating three-electrode audion in the other circuit.

Q. 31. In other words, it raises a doubt in your mind whether this two-electrode device would generate electric oscillations without this inductive coupling with the oscillating audion at the receiving end?

A. It seems to me that that is an obvious doubt in such a structure.

Q. 32. In your opinion, Mr. Stone, do you consider this a fair test of whether or not the two-electrode device with its circuits alone would generate electrical oscillations when using a three-electrode device?

A. It is by no means so conclusive as would be a test in which there was no coupling between those circuits, and there would be no difficulty in substituting another detector for the oscillating audion and using a tone wheel.

By the Court:

Q. 33. Have you made any experiments along that line?

A. I have made a number of experiments in an effort to cause a two-electrode valve to oscillate with one of the electrodes heated to incandescence, and I have never succeeded in making it oscillate, whereas, with the tubes with both

electrodes cold and a very much higher voltage, there was no difficulty whatever in making them oscillate.

[fol. 2575] Q. 34. What effect in your opinion does the oscillating characteristic of the audion at the receiving end have on the two-element valve in its oscillation in this present connection?

A. The possible effect is due to the fact that the electromotive force impressed upon that valve is no longer, owing to the coupling, a purely direct voltage or constant uni-directional voltage; it is a uni-directional voltage where the superimposed vibratory voltage comes from the oscillating audion in the receiving circuit. Moreover, the coupling is so arranged, the voltage developed by the coupling, that the oscillatory voltage produced at the terminals of the two-electrode bulb by that coupling is very much amplified by resonance in the circuit of Plaintiff's Exhibit 2.

Adjourned to March 12, 1919, at 12 m.

#### Trial Resumed

March 12, 1919, 12:00 m.

John Stone Stone: Resumes.

Direct Examination by Mr. Darby, Jr. (Continued):

Q. 35. Mr. Stone, have you read and do you understand the Fleming patent in suit?

A. I have and do.

Q. 36. Did you examine and did you understand the operation of the test apparatus that was demonstrated yesterday?

A. I examined the apparatus and understood its operation.

Q. 37. Will you please compare the arrangement, operation and functioning of the two-electrode valve device as shown and described in the Fleming patent with the arrangement, operation and function of the valve device used in the demonstration which was made yesterday?

A. The Fleming valve of the patent in suit as described and illustrated is included in a simple circuit, in an inductive relation with the antenna, which circuit comprises a coupling coil with the antenna and a galvanometer or other device capable of indicating the presence of a direct current in that circuit.

In the apparatus of the demonstration given in Court yesterday the two-electrode valve is connected to two branch circuits, one branch circuit comprising an iron cord impedance coil marked Z in Exhibit 2, the condenser marked C<sup>2</sup> and a battery of approximately 95 volts potential, in addition to the telephone receiver not marked on the drawing.

The other branch circuit comprises an inductance coil marked 2 in Plaintiff's Exhibit 2, a blocking condenser marked C<sup>1</sup> and a variable condenser marked C in that exhibit.

In the patent in suit there is no electromotive force impressed upon the two-electrode valve between the filament and grid save the minute alternating electromotive force induced in the oscillations in the antenna, and in the description contained in this patent the operation of the valve is described to be that of a simple rectifier, whereby this [fol. 2576] minute alternating impressed electromotive force is rectified and produces a small direct current in the simple circuit.

In contrast to this in the test yesterday a very large electromotive force is impressed upon the valve between its filament and plate, in addition to a very large oscillating electromotive force developed by the resonant circuit marked 2-3 by virtue of its coupling with the oscillating circuit of the three-electrode audion in the receiving circuit.

I will add here by interjection that the mode of couple employed resulted in a great magnification of the potential difference across the two-electrode valve represented in Plaintiff's Exhibit 2 by virtue of the resonant circuit 2-3 of Plaintiff's Exhibit 2. This magnification of voltage is not a small magnification, but in circuits of this type they amount to a multiplication of the impressed voltage a thousand fold.

Coming down to the disclosure of the mode of operation in the patent as compared with the mode of operation I apprehended in the apparatus of the demonstration yesterday, I find that in the patent in suit the valve is under such electrical conditions as to make it operate effectively as a simple rectifier. By contrast I find that in the test in Court yesterday owing to the presence of the large direct or unidirectional voltage due to the battery B-2 of Plaintiff's Exhibit 2 a blue glow extended from the filament to the plate, and I apprehend that under those circumstances the

action of the valve would cease to be an effective simple rectifier, but would possess different electrical properties characterized by a relatively extremely low resistance being established between the filament and the plate.

Q. 38. What elements if any do you find necessary to add to the circuits of the patent, or Fig. 1 of the patent in suit, in order to make the two-electrode valve generate oscillations, if it can be done?

A. Judging from the apparatus of the test, performed in Court yesterday, and for the sake of argument assuming that those conditions were sufficient to cause the two-electrode valve to execute sustained oscillations, I find that the elements necessarily added for this purpose are the addition of an iron cord impedance coil Z in Plaintiff's Exhibit 2, three condensers marked respectively C, C<sup>1</sup> and C-2, C being adjustable, a tap upon an inductance coil marked 2 in that exhibit and a battery of approximately 95 volts.

Q. 39. What is the relation of the condensers that are employed relative to the inductance that is employed in the transmitting end as illustrated in Plaintiff's Exhibit 2?

A. Calling the circuit to which you refer of the transmitting circuit the branch to the left hand of the valve in Exhibit 2, the elements are the condenser C<sup>1</sup>, the variable condenser C and the tap on the inductance coil; also the coupling coil associated with that inductance coil in case that coupling coil was effective in producing and maintaining the oscillations in the valve in that test.

Q. 40. And in fact the variable condenser C is not shown around the inductance coil; that is correct, is it not?

A. Yes; thus constituting the resonant circuit which I have referred to as 2-3.

[fol. 2577] Q. 41. Do you find any directions in the Fleming patent to add any of these elements?

A. No.

Q. 42. Do you find any directions in the Fleming patent which would make it possible to use a resonant circuit therewith, or which would direct you to use a resonant circuit in connection therewith?

A. I find no specific instructions to that effect.

Mr. Bull: I object to that; that is a matter that is for argument. We all agree as to what is in and what is not in the Fleming patent.

Q. 43. You have referred to the use of a high voltage employed in connection with tests yesterday of approximately 95 volts, as I recall the testimony of Mr. Weagant. Do you find anything in the Fleming patent which would as one familiar with the art at the date of the Fleming patent instruct you not to use a voltage sufficiently large to strike the so-called arc between the filament and the plate electrodes?

A. I do, because I find throughout the patent a description of its mode of operation as that of a rectifier or a device of uni-lateral conductivity, and as one skilled in the art I should feel that the patent directed me not to do anything that would militate against the operation of the apparatus as a rectifier.

Mr. Bull: I move to strike out the last part of that answer.

Motion granted; exception.

Mr. Bull: As a matter of fact, we are right back on the old case now.

The Court: Not only that, but this part of the testimony is quite contrary to the rule. It is perfectly all right to say that nowhere is such and such a thing, and I do not think that there is any disagreement really as to the facts between both sides, but when he starts in to say that he as one skilled in the art finds that there is in effect or by virtue of his reasons or his inferences a direction not to do something or another, that is merely argument.

Mr. Darby, Jr.: We will simply let it rest there.

Q. 44. As one skilled in the art would you say that the generation of the oscillations by the Fleming two-electrode device, if it may be made to generate electrical oscillations, would be an expected result from the directions, description and illustration contained in the Fleming patent in suit?

Mr. Bull: I object to that. Objection sustained; exception.

Q. 45. Now confining myself strictly to the functioning of the two-electrode device as shown and described in the Fleming patent in suit, the electromotive force in the plate filament circuit is an alternating electromotive force with

minute high frequency alternating voltage, I believe you stated in your answer to one of your previous questions?

A. It is.

Q. 46. And that minute high frequency alternating voltage is induced by the received radio oscillations in the antenna circuit; that is correct, is it not?

A. It is.

Q. 47. So that the result is that rectification takes place [fol. 2578] and a uni-directional current is thereby developed in that circuit?

A. Yes.

Q. 48. Is any change in that functioning of the device effected by reducing the minute alternating high frequency electromotive force by replacing the minute alternating high frequency electromotive force by a direct or uni-directional electromotive force of high voltage?

A. Yes. The functioning is completely different. In one case the alternating electromotive force acting upon the two electrodes of the device causes a rectification action to take place, resulting in a uni-directional current in the circuit. In the second case, the large electromotive force impressed upon the valve may either produce no current at all if poled in one direction, or may produce a large uni-directional current in the opposite direction, but in either case there would be no rectification.

Q. 49. You heard Mr. Waterman's testimony when the apparatus was demonstrated yesterday to the effect that he did not believe the blue glow extended between the plate and filament, did you not?

A. Yes.

Q. 50. Do you agree with Mr. Waterman's statement?

A. I do not.

Q. 51. What would be the effect on the functioning of the device if the blue glow did not extend between the filament and plate?

A. Assuming that it developed sustained oscillations when the blue glow extended between the filament and the plate in my opinion those sustained oscillations would not have been developed if the blue glow did not extend between the filament and the plate.

Q. 52. What would be the effect on the functioning of the apparatus demonstrated yesterday if the blue glow were suppressed or eliminated?

A. In my opinion the valve would become a simple rectifier and would under no circumstances develop sustained oscillations.

Q. 53. Referring again to the coupling back of the oscillating circuit, of the oscillating audion that was employed in the receiving end of the apparatus, what advantage for the test that was given in that test apparatus was secured from the arrangement employing that coupling back for the purpose of that test?

A. Owing to the fact that that coupling was made with the resonant circuit 2-3 illustrated in Plaintiff's Exhibit 2, it developed a high potential oscillating electromotive force at the terminals of the valve, and this would tend to disturb its equilibrium which might in my opinion possibly result in causing it to sustain oscillations which in its absence would not be developed.

Q. 54. Do you know of any practical use to which the arrangement employed for the demonstration yesterday with the receiver coupled back on the transmitter could be put in radio communications using the apparatus of the test apparatus on the table?

A. No. I can see no useful purpose to which it could be applied in view of the fact that the three-electrode bulb was itself developing a sustained train of oscillation which could have been used for any purpose that this apparatus was used.

Q. 55. You have heard Mr. Waterman's testimony with regard to the theory of reversibility of function; you heard Mr. Waterman's testimony?

[fol. 2579] A. I did.

Q. 56. Mr. Waterman's testimony was to the effect that the valve as a detector and rectifier is merely the reversal of the valve as a generator, or, in other words, that this is merely the phenomenon of the reversibility of function; do you agree with Mr. Waterman?

A. I do not.

Q. 57. Will you please explain that?

A. The reversible phenomena are the class of phenomena which may be best described by specific examples, as, for instance, the motor transformer which is an apparatus which when you supply it with direct current at one set of terminals will develop an alternating current in the other set of terminals, and conversely when you apply an alternating

current to the second set of terminals a direct current will be developed at the first set of terminals.

Similarly, in the case of the thermopile, if you heat one end of the thermopile, cooling the other, it will develop an electric current, and conversely if you pass an electric current through the thermopile it will heat one of these terminals and cool the other. Those are strictly reversible phenomena. But an apparatus which has been put under entirely new conditions as is the case with the two-electrode valve, assuming that it does produce sustained oscillations, in order to have it reverse its function, is not the case of the simple reversal of function; it is not a reversible phenomena that is taking place.

Cross-examination.

By Mr. Bull:

X Q. 58. I understand you to say that in this apparatus as it was operating yesterday there was present such a blue glow as would put the two-electrode valve out of action as a detector; am I right about that?

A. It would be sufficient to very greatly diminish its function as a detector.

X Q. 59. And practically put it out of commission actually as a detector?

A. Under some circumstances it would render it completely ineffective in that respect.

X Q. 60. Did you not hear this same valve with the same conditions used as a detector yesterday?

A. I do not remember.

X Q. 61. You do not remember asking Mr. Weagant to do something and Mr. Weagant misunderstood what you wanted him to do and he turned the apparatus around as we had offered to do so that the three-electrode end acted as the generator and the two-electrode end acted as the receiver?

A. I was not aware that he was doing any such thing; he may have been doing it.

X Q. 62. I was standing there and I heard him say, "Oh, excuse me, I thought that is what you wanted me to do."

A. He told me I was listening on the wrong set of telephones.

X Q. 63. You did hear something at that time?

A. I did not know what he was doing.

X Q. 64. But you did hear signals?

A. I heard a noise, it sounded to me like an arc.

X Q. 65. One of those high musical ares?

A. Not musical; on the contrary it was just a roar.

[fol. 2580] X Q. 66. You have referred several times to the presence of an inductive coupling; you did not testify in the main case, did you?

A. No, I had nothing to do with it.

X Q. 67. Would you be surprised that precisely that same inductive coupling was used in every experiment that was made in the Court by both sides in this case?

A. I do not know what the experiments were in that case; I have not read the record.

X Q. 68. Experiments for sending and receiving; would you be surprised?

A. I could not be surprised unless I knew what the tests were and I never read the record in that case.

X Q. 69. You said that by reason of that inductive coupling you were not sure that the oscillations of the three-element valve were what were causing the two-element valve to oscillate?

A. Substantially that.

X Q. 70. And you say that notwithstanding the fact that the two valves were oscillating at different rates?

A. There appeared to be beats.

X Q. 71. There were beats?

A. Yes.

X Q. 72. Then they were oscillating at different rates?

A. I think that they were oscillating at different rates from the presence of beats.

X Q. 73. Do you think it at all probable that oscillations at one rate would set up in the other valves oscillations of a different rate?

A. I think they might very well where the oscillations produced were of the very high frequencies, and the two circuits were slightly out of tune.

X Q. 74. Is it not true that this inductive coupling which we are talking about causes the receiving circuit to abstract energy from the transmitting circuit?

A. I think it undoubtedly causes a swapping of energy between the two circuits.

X Q. 75. But you would not admit that it would cause them to abstract energy?

A. Both abstract and return.

Re-direct examination.

By Mr. Darby, Jr.:

R. D. Q. 76. You did not state in your testimony, did you, that when the blue glow occurred in a two-electrode device that that spoiled the electrode device for future use, did you?

A. No; I did not intend to imply anything of that kind.

Mr. Bull: I did not intend to imply any thing of the kind either.

Mr. Darby, Jr.: I gathered from Mr. Bull's question that on using this two-electrode device as a receiver that the inference was raised that Mr. Stone was testifying that the blue glow made it impossible for it to be used as a receiver.

Mr. Bull: I probably must apologize to my friend Mr. Darby. My scientific language was weak; my exact words were "put out of action"; I meant temporarily; I did not mean permanently.

Mr. Darby, Jr.: The file wrapper of the Fleming patent is in evidence as an exhibit, Exhibit W, in the main case. I would like also to use it in this case; do you desire it as a separate exhibit?

[fol. 2581] Mr. Bull: I think all the evidence in the main case, this is merely under a supplemental bill, all the other evidence is in this case.

The Court: There is no question about that. Let it be noted for convenience at this point that Exhibit W is the file wrapper.

Defendant's Proofs closed.

#### Plaintiff's Rebuttal Proofs

FRANK L. WATERMAN, recalled in rebuttal, testifies as follows:

Direct examination.

By Mr. Bull:

Q. 181. Mr. Waterman, you heard Professor Stone say that he believed the two-element valve could not operate as a generator of wireless waves unless the blue glow was present. Does that statement accord with your experience with these lamps?

A. It does not.

Q. 182. Are you prepared to demonstrate the operation of this two-element valve to the court as a generator in the absence of the blue glow?

A. We have a bulb there which last night generated without a blue glow and again this morning. I will be glad to try and see if we can do the same thing again.

Q. 183. You have heard Professor Stone state that the presence of the three-element valve in the receiving station might have been the cause of the oscillations of the two-element valve in the generating part of the apparatus. You also heard, I suppose, Professor Stone indicate a desire to see the two-element valve operate as a generator in circuits which did not include any three-element valve; is that true?

A. I did.

Q. 184. Are you prepared to demonstrate to the court the operation of the two-element valve as a generator in circuits which do not include any three-element valve?

A. I am, with some make-shift apparatus. I tried last night to get a commercial ticker, as it is called, without success, but by the use of a file and a wire scraped over it we break up the oscillations so that they may be received with the ordinary crystal detector, that simply being a rough way of imitating the action of the ticker.

Q. 185. Did you hear me in an informal way last evening after adjournment ask Professor Stone if he happened to have a ticker apparatus in his pocket and he said he did not?

A. I did.

Q. 186. Did you also hear Mr. Weagant ask him if he would be satisfied if the demonstration were made with an ordinary file?

A. I did.

Mr. Darby, Jr.: If your Honor please, as I recall it, that is not the way the question was put to Mr. Stone. There was a qualification that Mr. Bull has not expressed.

Mr. Bull: If you will correct me.

Mr. Darby, Jr.: Mr. Stone, as I recall, stated that the file could be used in the receiving circuit in place of the inter-[fol. 2582] rupter which he expressly mentioned could be used in the receiving circuit.

Mr. Bull: I did not know anything about that. We asked him if we could use a file.

Mr. Darby, Sr.: If new tests are going to be made we ought to have an opportunity to explain them.

Mr. Bull: I suppose you will have an opportunity to explain them, but you will understand these tests are not in any sense new tests, they are tests which your Honor almost indicated yesterday his desire to see.

The Court: Yes; I did want to see it.

Mr. Bull: And we have with such other apparatus as we could get together overnight, we are prepared to show the operation.

By Mr. Bull:

Q. 187. Will you proceed to make those demonstrations, and if you can do so make them both at one time.

A. If I can get Mr. Weagant to operate the apparatus; he is familiar with it.

The Court: Mr. Weagant, will you just state for the record what you are doing?

Mr. Weagant: In this test I am going to operate the two-element Fleming valve as a generator and I am going to use the same receiving set as was used yesterday with the exception that I employ a crystal detector to detect the oscillations.

Mr. Bull: In place of the three-element valve?

Mr. Weagant: In place of the three-element valve. These oscillations, being continuous oscillations, will not make any sound in the detector unless they are broken up in some way, or unless we have the beat as we had yesterday. So I am going to break these up at the transmitter here with a file and a light piece of wire connected across the points where the key is connected in the transmitter so that that merely disturbs the oscillations that are being generated in this coil, and there will be heard in the telephone receivers a scratching corresponding to my drawing the file across, and I shall show that that scratching stops if I stop the valve, or if I throw the tuner out of tune, showing that it is due to the oscillations.

The Witness: May I make a statement? Mr. Weagant used the expression "disturbing the oscillations". That I think is not quite an apt expression of what happens. We are merely replacing the sending key by the file which makes

the interruptions at such rapidity as will correspond to a rate that the ear can obtain.

Mr. Weagant: Yes.

The Witness: There is no blue glow in the valve, if your Honor will notice.

By Mr. Bull:

Q. 188. Will you explain, Mr. Waterman, the demonstration which has just been made?

A. The demonstration is identical with that which was made yesterday, with three exceptions. The valve which is [fol. 2583] being used is a different valve and one which on account of a higher vacuum, or some characteristic that we do not know, does not require the blue glow in order to oscillate. The detector employed is an ordinary crystal detector, and the three-element valve which was employed yesterday certainly not in operation, but it has been removed from the table entirely. I may say if I may interject that the sole reason why the valve was employed as the receiver was that I apprehended that the court would desire to receive oscillations with the two-element valve as well as transmit, and that was the convenient way of doing it, and furthermore, the set is a perfectly standard regular set without modification or alteration of any kind, and, further, was immediately and readily available to bring here.

The third difference is that the oscillations, or rather the signals sent, are broken up in this instance by what is in the parlance of the art called a chopper, the file and the wire imitating the chopper. That breaking up may be done at either the transmitting or the receiving station. I have had it put where it is for two reasons. In the first place, the circuit to which it is now connected is not one which is in any way associated with the battery. Hence, it cannot by any line of argument be reasoned that the operation of the wire over the file was affecting a battery current, and that it was not the valve that was operating. The second reason was that the coil is already tapped for the purpose while the commercial apparatus which we had is not tapped for that purpose, and to connect it across a whole coil would be apt to interfere with the tuning of the coil.

The operation was as follows: Upon the lighting of the filament by merely connecting the battery to it, the two-element valve started to oscillate. Those oscillations were re-

A. Yes; that is correct.

Q. 40. That is to say, he selected some old bulbs for the purpose of the demonstration to the court?

A. Yes.

Mr. Darby, Jr.: I believe Mr. Waterman also said that he tried them and picked out those which would oscillate.

Mr. Bull: Yes.

JOHN STONE STONE, a witness called in behalf of the defendant, being duly sworn, testifies as follows:

Mr. Darby, Jr.: May I ask if you will concede Mr. Stone's qualifications?

Mr. Bull: I certainly will.

Direct examination:

By Mr. Darby, Jr.:

Q. 1. How long have you been familiar with vacuum tubes?

A. Since about 1892.

Q. 2. How long have you been familiar with the use of vacuum tubes with respect to high frequency work?

A. My first experience with vacuum tubes in high frequency work was some time in 1893.

Q. 3. Have you had occasion to make a thorough investigation and study of vacuum tubes in the various uses to which they may be put?

A. I have had considerable experience with vacuum tubes, the matter of detecting electrical oscillations and generating electrical oscillations.

Q. 4. And amplification?

A. Some.

Q. 5. You witnessed and took part in the demonstration of this apparatus that had been set up by the plaintiff I believe?

A. Yes.

Q. 6. You noticed the blue glow effect that took place in the Fleming two-electrode structure when it was as the plaintiff states generating electrical oscillations?

A. Yes.

Q. 7. Will you please describe in your own language what produced that blue glow, its effect on the circuit, and what

you can tell us in connection with the phenomenon of the appearance of that blue glow.

A. The blue glow is a phenomenon which takes place in a vacuum tube when the potential difference, or the electromotive force acting between the two electrodes, reaches such a high value as to produce a sudden decrease in the electrical resistance between those electrodes. I will not go into the scientific explanation of the mechanism that produces that sudden diminution of resistance, and will say that it is a very well recognized phenomenon, however, and amongst operators and the like, the character of users of audions and valves, it is generally spoken of as striking an arc. Personally I do not consider that the phenomenon is identical with the electric arc, but it is in the same nature an arc in so far as its effect upon the resistance of the space between the electrodes is concerned.

[fol. 2570] Q. 8. Might I ask when you say striking an arc in the colloquial, if you please, the interpretation of that, do you mean striking an arc between the electrodes?

A. Yes.

Q. 9. Might I ask is the function of that blue glow the same as the arc?

A. Functionally it seems to operate in much the same way as if a true arc were struck between the electrodes. It differs from a true arc between the electrodes only in that the diminution of the resistance which it establishes between those electrodes is not so great as would be the case if a true arc were struck between them.

Q. 10. What is the effect of that blue glow or arc on the two-electrode device for detection purposes?

A. As soon as the blue glow commences to appear in a rectifying valve, vacuum tube valve, its qualities as a rectifier, and therefore as a detector, begin to wane very rapidly, and as the blue glow increases until it finally reaches from one electrode to the other, the deleterious effect upon the detecting function of the valve becomes greater and greater until finally the valve becomes extremely inefficient or inoperative for detection purposes. And when I speak of this diminution of efficiency in the valve as a detector I do not refer to matters of small percentage, but the change is so great that a detector which may be receiving easily readable signals may cease to develop audible signals even, and a valve which is receiving quite loud signals may under the

influence of the blue glow become so inefficient that the signals become unreadable.

Q. 11. Is it possible to make a two-electrode device generate oscillations without striking that arc which you refer to?

A. So far as my experience goes, and theoretical investigation that I have made of the simple valve, or rectifier, I am convinced that it cannot oscillate unless the blue glow or so-called arc exists between the electrodes.

Q. 12. In other words, striking the arc which I believe is admitted causes the blue glow to appear, is absolutely essential and necessary for the two-electrode device to act as a generator of oscillations?

A. That is my opinion.

The Court: Then what follows from that?

Mr. Darby, Jr.: This follows, if your Honor please; it shows conclusively that you have to completely eliminate Fleming's invention to use it as a generator; in other words, the contention that it will detect is absolutely opposed to the contention that it will act for generation purposes. The minute that it strikes an arc, the minute that it generates oscillations, it absolutely ceases to rely upon its detection properties for operation.

Q. 13. May I ask if you are familiar with a similar blue glow effect in the three-electrode audion?

A. Yes.

Q. 14. Is the striking of the arc, or causing this blue glow effect to appear, necessary for the operation of the audion?

A. No; the presence of the blue glow or so-called arc militates greatly against the efficient operation of the three-electrode audion as a detector, and it also militates against its operation as an oscillion or oscillator.

[fol. 2571] Q. 15. Would the audion operate if the blue glow effect appears?

A. It begins to cease to operate effectively as soon as the blue glow appears.

Q. 16. That is what has been commonly known as paralyzing the audion, is it not?

A. Yes; the operators use that word.

Q. 17. And means have got to be taken to prevent the paralyzing of the audion or to immediately dissipate that condition as soon as it appears; is that correct?

A. Yes.

Q. 18. I believe I understood you to say that you personally knew that a two-electrode device would generate high frequency oscillations about 1893.

Mr. Bull: I object to that, if they are going into the prior art. I do not know whether that will anticipate our patent or not.

Mr. Darby, Jr.: I want to lead up to the point of when the discovery was made of the oscillation and generation by a three-electrode device as distinguished from a two-electrode device.

Mr. Bull: Ask him that question.

Mr. Darby, Jr.: I have asked that question; I wanted to be correct as to my starting point before proceeding.

The Court: Reframe the question.

Q. 19. Will you please explain how you discovered in 1893 that a two-electrode device would generate electrical oscillations?

The Court: I do not get this at all.

Q. 20. I will ask you this: when did you first obtain knowledge that the three-electrode device would generate electrical oscillation?

A. In 1912 I received that knowledge indirectly in this way: I received a letter from Dr. DeForest who was out on the Pacific Coast informing me that he had discovered that his audion would amplify alternating currents, whereupon as an old telephone engineer I wrote him a letter stating that if it would amplify telephone currents or any other currents, it would certainly oscillate, and pointed out to him what particular kind of circuits he would have to use in connection with his audion in order to prevent it from oscillating in case he wanted to do so in its use as a telephone amplifier, and I needed no further information than the fact that the audion would amplify to know that it would oscillate, nor would any other competent telephone engineer need to know anything more.

Q. 21. In what connection were the two-electrode vacuum tubes that you were familiar with in 1893 used; that is, for what purpose were they used?

Mr. Bull: I object to that.

Mr. Darby, Jr.: If your Honor please, this is of the two-electrode device for generating high frequency electrical

oscillation. I want to prove by this witness that in 1893, two-electrode devices for the production of high frequency oscillation were known, and further than that, that the only difference between this device and what was known [fol. 2572] and used at that time for that purpose was that in Fleming they used a hot electrode, one electrode is heated, whereas in the old device one electrode was not heated. I want to further prove that so far as the operation of a generator of electrical oscillations is concerned, it makes no difference whether that electrode is heated or not, and further that the actual heating of the electrode is detrimental to its generation of electrical oscillations. I think that is wholly pertinent.

Mr. Bull: In the first place, I object to their going into the prior art. That is simply an effort to anticipate our patent, as I understand it. In the second place, I do not think I could have correctly heard what Mr. Stone said because my understanding is that we are here simply because Mr. Stone on the motion filed an affidavit in which he said you could not make a two-electrode device work and I think he is asking him if he did not make a two-electrode device generate way back in 1893.

The Court: Your argument as to certain proofs covered several points. I alone directed myself to one. I think any testimony which in effect is in the nature of anticipation of the state of the art prior to Fleming is not admissible in this case. Now, that is the theoretical side. Now, the practical side is this, that the books have now grown full of cases which show that certainly not in 1893 did any person have any conception of the power of generation and oscillation in its present relation; that is as certain as anything can be. A man might look back for all I know on some theoretical business about oscillations and all that sort of thing, but from the radio standpoint to go into the dark ages and the past ages to find out what happened in 1893 to my mind is utterly immaterial.

Now, on the question as to what the two-electrode will do and what a three-electrode will do, that is a different proposition. There Professor Stone's experience as a scientific man and an expert is entirely relevant along the questions which are intended to show how these things work and what in fact they do, and so on. I am perfectly clear from the testimony, I do not believe anybody disputes the fact,

that the oscillating properties or the characteristics were unknown in this relation to the scientific world until a considerable number of years after Fleming invention. As I said this morning, if the thing does oscillate, if the Fleming valve does generate, the next question is purely a question of law.

Mr. Darby, Jr.: If your Honor please, I ask you not to forget one point and that is that the plaintiff in this case is seeking to include the oscillating audion as an infringement of their patent, and to do so they have got to broaden the scope of their claims to enable them to do so.

The Court: That is a question of argument; that has got nothing to do with this 1893 proposition; I will sustain the objection.

Mr. Darby, Jr.: Exception.

Q. 22. Mr. Stone, is the heated electrode or hot electrode of the Fleming two-electrode device absolutely essential [fol. 2573] to its use as a rectifier?

A. Yes. I will say that the heating of the filament electrode in the Fleming valve is essential to its operation.

Q. 23. If the hot electrode of the Fleming valve is not heated; in other words, if the heating battery is omitted, and a sufficient voltage is employed, would the device generate electrical oscillations?

Mr. Bull: I object to that; I think it is utterly immaterial.

The Court: What is your theory on that?

Mr. Darby, Jr.: My theory is this: my next question which I intended to ask to bring it out, was if the filament was not heated, it would generate electrical oscillations more efficiently than if it were heated.

The Court: Suppose it did; then go and use one that is not heated.

Mr. Darby, Jr.: Then, of course, they would not have the Fleming invention there.

The Court: You have got one electrode that is heated; they have one that is heated. Now, you can use the finest kind of cold electrodes in the world and they do not care anything about it.

Mr. Darby, Jr.: Suppose in the three-electrode device, the hot electrode is absolutely essential for its work, whereas in the two-electrode device it is detrimental; does not that alter the situation, as a generator?

The Court: I will sustain the objection on the ground that the question is immaterial and irrelevant.

Mr. Darby, Jr.: Exception.

Q. 24. Will you examine those two circuits, Plaintiff's Exhibits 2 and 3; referring to the apparatus which those circuits, for the sake of convenience represent, you will note that an oscillating audion at the receiving end is employed, and you will further note that the receiving end is inductively coupled to the transmitting end; that is correct, is it not?

A. It is correct as to the apparatus of the demonstration but it is not shown in these exhibits as far as I can see.

Q. 25. You mean that the inductive coupling between the receiving and the transmitting is not shown?

A. Yes; that is what I mean.

Q. 26. In the receiving system the electrical oscillations are being generated, are they not?

A. Yes.

Q. 27. What effect would the electrical oscillations generated in the receiving system have upon whether or not the two-electrode device is actually generating electrical oscillations?

A. It is very difficult to say. The oscillations which are generated in the receiving circuit or the oscillating three-electrode audion, are in part due to the oscillation circuit of the two-electrode valve, and what effect that would have upon the oscillation of that circuit, or the maintenance of the oscillations of that circuit, is very difficult to say; it is impossible to say *a priori*. The only way that I can imagine the effect of these oscillations to be determined would be to substitute a non-oscillation producing detector in a receiving circuit, and coupled with the interrupter, breaking [fol 2574] up the train of continuous waves, and then see whether the two-electrode valve would oscillate in the transmitter without the coupling between the transmitter and the receiver.

Q. 28. What is the nature of the coupling between the oscillating audion system and the receiving system?

A. It is difficult to say what it is because the wires run back of the board, but I fancy it is a simple inductive coupling.

Mr. Bull: If you want any wires straightened out for you we will be glad to help you.

The Witness: I have examined it and find it is a simple inductive coupling between the transmitter and receiver as I had previously supposed.

Q. 29. What ordinarily is the effect of an inductive coupling between an oscillating circuit and another circuit?

A. Well, in the well known case of the grid plate circuit of the three-electrode audion, and the filament grid circuit, it is essential in causing the device to operate. A similar action might or might not take place here by the coupling between the plate filament circuit of the oscillating audion and the filament plate circuit of the two-electrode valve.

Q. 30. By the use of this three-electrode oscillating audion in this demonstration apparatus, coupled as shown by the apparatus itself, does it raise a doubt in your mind as to whether or not the two-electrode device is generating electrical oscillations of a degree sufficient to be detected?

A. No; it is undoubtedly generating those oscillations, but the coupling makes me doubt whether the two-electrode tube would oscillate in that circuit, except for the coupling with the oscillating three-electrode audion in the other circuit.

Q. 31. In other words, it raises a doubt in your mind whether this two-electrode device would generate electric oscillations without this inductive coupling with the oscillating audion at the receiving end?

A. It seems to me that that is an obvious doubt in such a structure.

Q. 32. In your opinion, Mr. Stone, do you consider this a fair test of whether or not the two-electrode device with its circuits alone would generate electrical oscillations when using a three-electrode device?

A. It is by no means so conclusive as would be a test in which there was no coupling between those circuits, and there would be no difficulty in substituting another detector for the oscillating audion and using a tone wheel.

By the Court:

Q. 33. Have you made any experiments along that line?

A. I have made a number of experiments in an effort to cause a two-electrode valve to oscillate with one of the electrodes heated to incandescence, and I have never succeeded in making it oscillate, whereas, with the tubes with both

electrodes cold and a very much higher voltage, there was no difficulty whatever in making them oscillate.

[fol. 2575] Q. 34. What effect in your opinion does the oscillating characteristic of the audion at the receiving end have on the two-element valve in its oscillation in this present connection?

A. The possible effect is due to the fact that the electromotive force impressed upon that valve is no longer, owing to the coupling, a purely direct voltage or constant uni-directional voltage; it is a uni-directional voltage where the superimposed vibratory voltage comes from the oscillating audion in the receiving circuit. Moreover, the coupling is so arranged, the voltage developed by the coupling, that the oscillatory voltage produced at the terminals of the two-electrode bulb by that coupling is very much amplified by resonance in the circuit of Plaintiff's Exhibit 2.

Adjourned to March 12, 1919, at 12 m.

#### Trial Resumed

March 12, 1919, 12:00 m.

John Stone Stone: Resumes.

Direct Examination by Mr. Darby, Jr. (Continued):

Q. 35. Mr. Stone, have you read and do you understand the Fleming patent in suit?

A. I have and do.

Q. 36. Did you examine and did you understand the operation of the test apparatus that was demonstrated yesterday?

A. I examined the apparatus and understood its operation.

Q. 37. Will you please compare the arrangement, operation and functioning of the two-electrode valve device as shown and described in the Fleming patent with the arrangement, operation and function of the valve device used in the demonstration which was made yesterday?

A. The Fleming valve of the patent in suit as described and illustrated is included in a simple circuit, in an inductive relation with the antenna, which circuit comprises a coupling coil with the antenna and a galvanometer or other device capable of indicating the presence of a direct current in that circuit.

In the apparatus of the demonstration given in Court yesterday the two-electrode valve is connected to two branch circuits, one branch circuit comprising an iron cord impedance coil marked Z in Exhibit 2, the condenser marked C2 and a battery of approximately 95 volts potential, in addition to the telephone receiver not marked on the drawing.

The other branch circuit comprises an inductance coil marked 2 in Plaintiff's Exhibit 2, a blocking condenser marked C<sup>1</sup> and a variable condenser marked C in that exhibit.

In the patent in suit there is no electromotive force impressed upon the two-electrode valve between the filament and grid save the minute alternating electromotive force induced in the oscillations in the antenna, and in the description contained in this patent the operation of the valve is described to be that of a simple rectifier, whereby this [fol. 2576] minute alternating impressed electromotive force is rectified and produces a small direct current in the simple circuit.

In contrast to this in the test yesterday a very large electromotive force is impressed upon the valve between its filament and plate, in addition to a very large oscillating electromotive force developed by the resonant circuit marked 2-3 by virtue of its coupling with the oscillating circuit of the three-electrode audion in the receiving circuit.

I will add here by interjection that the mode of couple employed resulted in a great magnification of the potential difference across the two-electrode valve represented in Plaintiff's Exhibit 2 by virtue of the resonant circuit 2-3 of Plaintiff's Exhibit 2. This magnification of voltage is not a small magnification, but in circuits of this type they amount to a multiplication of the impressed voltage a thousand fold.

Coming down to the disclosure of the mode of operation in the patent as compared with the mode of operation I apprehended in the apparatus of the demonstration yesterday, I find that in the patent in suit the valve is under such electrical conditions as to make it operate effectively as a simple rectifier. By contrast I find that in the test in Court yesterday owing to the presence of the large direct or unidirectional voltage due to the battery B-2 of Plaintiff's Exhibit 2 a blue glow extended from the filament to the plate, and I apprehend that under those circumstances the

action of the valve would cease to be an effective simple rectifier, but would possess different electrical properties characterized by a relatively extremely low resistance being established between the filament and the plate.

Q. 38. What elements if any do you find necessary to add to the circuits of the patent, or Fig. 1 of the patent in suit, in order to make the two-electrode valve generate oscillations, if it can be done?

A. Judging from the apparatus of the test, performed in Court yesterday, and for the sake of argument assuming that those conditions were sufficient to cause the two-electrode valve to execute sustained oscillations, I find that the elements necessarily added for this purpose are the addition of an iron cord impedance coil Z in Plaintiff's Exhibit 2, three condensers marked respectively C, C<sup>1</sup> and C-2, C being adjustable, a tap upon an inductance coil marked 2 in that exhibit and a battery of approximately 95 volts.

Q. 39. What is the relation of the condensers that are employed relative to the inductance that is employed in the transmitting end as illustrated in Plaintiff's Exhibit 2?

A. Calling the circuit to which you refer of the transmitting circuit the branch to the left hand of the valve in Exhibit 2, the elements are the condenser C<sup>1</sup>, the variable condenser C and the tap on the inductance coil; also the coupling coil associated with that inductance coil in case that coupling coil was effective in producing and maintaining the oscillations in the valve in that test.

Q. 40. And in fact the variable condenser C is not shown around the inductance coil; that is correct, is it not?

A. Yes; thus constituting the resonant circuit which I have referred to as 2-3.

[fol. 2577] Q. 41. Do you find any directions in the Fleming patent to add any of these elements?

A. No.

Q. 42. Do you find any directions in the Fleming patent which would make it possible to use a resonant circuit therewith, or which would direct you to use a resonant circuit in connection therewith?

A. I find no specific instructions to that effect.

Mr. Bull: I object to that; that is a matter that is for argument. We all agree as to what is in and what is not in the Fleming patent.

Q. 43. You have referred to the use of a high voltage employed in connection with tests yesterday of approximately 95 volts, as I recall the testimony of Mr. Weagant. Do you find anything in the Fleming patent which would as one familiar with the art at the date of the Fleming patent instruct you not to use a voltage sufficiently large to strike the so-called arc between the filament and the plate electrodes?

A. I do, because I find throughout the patent a description of its mode of operation as that of a rectifier or a device of uni-lateral conductivity, and as one skilled in the art I should feel that the patent directed me not to do anything that would militate against the operation of the apparatus as a rectifier.

Mr. Bull: I move to strike out the last part of that answer.

Motion granted; exception.

Mr. Bull: As a matter of fact, we are right back on the old case now.

The Court: Not only that, but this part of the testimony is quite contrary to the rule. It is perfectly all right to say that nowhere is such and such a thing, and I do not think that there is any disagreement really as to the facts between both sides, but when he starts in to say that he as one skilled in the art finds that there is in effect or by virtue of his reasons or his inferences a direction not to do something or another, that is merely argument.

Mr. Darby, Jr.: We will simply let it rest there.

Q. 44. As one skilled in the art would you say that the generation of the oscillations by the Fleming two-electrode device, if it may be made to generate electrical oscillations, would be an expected result from the directions, description and illustration contained in the Fleming patent in suit?

Mr. Bull: I object to that. Objection sustained; exception.

Q. 45. Now confining myself strictly to the functioning of the two-electrode device as shown and described in the Fleming patent in suit, the electromotive force in the plate filament circuit is an alternating electromotive force with

minute high frequency alternating voltage, I believe you stated in your answer to one of your previous questions?

A. It is.

Q. 46. And that minute high frequency alternating voltage is induced by the received radio oscillations in the antenna circuit; that is correct, is it not?

A. It is.

Q. 47. So that the result is that rectification takes place [fol. 2578] and a uni-directional current is thereby developed in that circuit?

A. Yes.

Q. 48. Is any change in that functioning of the device effected by reducing the minute alternating high frequency electromotive force by replacing the minute alternating high frequency electromotive force by a direct or uni-directional electromotive force of high voltage?

A. Yes. The functioning is completely different. In one case the alternating electromotive force acting upon the two electrodes of the device causes a rectification action to take place, resulting in a uni-directional current in the circuit. In the second case, the large electromotive force impressed upon the valve may either produce no current at all if poled in one direction, or may produce a large uni-directional current in the opposite direction, but in either case there would be no rectification.

Q. 49. You heard Mr. Waterman's testimony when the apparatus was demonstrated yesterday to the effect that he did not believe the blue glow extended between the plate and filament, did you not?

A. Yes.

Q. 50. Do you agree with Mr. Waterman's statement?

A. I do not.

Q. 51. What would be the effect on the functioning of the device if the blue glow did not extend between the filament and plate?

A. Assuming that it developed sustained oscillations when the blue glow extended between the filament and the plate in my opinion those sustained oscillations would not have been developed if the blue glow did not extend between the filament and the plate.

Q. 52. What would be the effect on the functioning of the apparatus demonstrated yesterday if the blue glow were suppressed or eliminated?

A. In my opinion the valve would become a simple rectifier and would under no circumstances develop sustained oscillations.

Q. 53. Referring again to the coupling back of the oscillating circuit, of the oscillating audion that was employed in the receiving end of the apparatus, what advantage for the test that was given in that test apparatus was secured from the arrangement employing that coupling back for the purpose of that test?

A. Owing to the fact that that coupling was made with the resonant circuit 2-3 illustrated in Plaintiff's Exhibit 2, it developed a high potential oscillating electromotive force at the terminals of the valve, and this would tend to disturb its equilibrium which might in my opinion possibly result in causing it to sustain oscillations which in its absence would not be developed.

Q. 54. Do you know of any practical use to which the arrangement employed for the demonstration yesterday with the receiver coupled back on the transmitter could be put in radio communications using the apparatus of the test apparatus on the table?

A. No. I can see no useful purpose to which it could be applied in view of the fact that the three-electrode bulb was itself developing a sustained train of oscillation which could have been used for any purpose that this apparatus was used.

Q. 55. You have heard Mr. Waterman's testimony with regard to the theory of reversibility of function; you heard Mr. Waterman's testimony?  
[fol. 2579] A. I did.

Q. 56. Mr. Waterman's testimony was to the effect that the valve as a detector and rectifier is merely the reversal of the valve as a generator, or, in other words, that this is merely the phenomenon of the reversibility of function; do you agree with Mr. Waterman?

A. I do not.

Q. 57. Will you please explain that?

A. The reversible phenomena are the class of phenomena which may be best described by specific examples, as, for instance, the motor transformer which is an apparatus which when you supply it with direct current at one set of terminals will develop an alternating current in the other set of terminals, and conversely when you apply an alternating

current to the second set of terminals a direct current will be developed at the first set of terminals.

Similarly, in the case of the thermopile, if you heat one end of the thermopile, cooling the other, it will develop an electric current, and conversely if you pass an electric current through the thermopile it will heat one of these terminals and cool the other. Those are strictly reversible phenomena. But an apparatus which has been put under entirely new conditions as is the case with the two-electrode valve, assuming that it does produce sustained oscillations, in order to have it reverse its function, is not the case of the simple reversal of function; it is not a reversible phenomena that is taking place.

Cross-examination.

By Mr. Bull:

X Q. 58. I understand you to say that in this apparatus as it was operating yesterday there was present such a blue glow as would put the two-electrode valve out of action as a detector; am I right about that?

A. It would be sufficient to very greatly diminish its function as a detector.

X Q. 59. And practically put it out of commission actually as a detector?

A. Under some circumstances it would render it completely ineffective in that respect.

X Q. 60. Did you not hear this same valve with the same conditions used as a detector yesterday?

A. I do not remember.

X Q. 61. You do not remember asking Mr. Weagant to do something and Mr. Weagant misunderstood what you wanted him to do and he turned the apparatus around as we had offered to do so that the three-electrode end acted as the generator and the two-electrode end acted as the receiver?

A. I was not aware that he was doing any such thing; he may have been doing it.

X Q. 62. I was standing there and I heard him say, "Oh, excuse me, I thought that is what you wanted me to do."

A. He told me I was listening on the wrong set of telephones.

X Q. 63. You did hear something at that time?

A. I did not know what he was doing.

X Q. 64. But you did hear signals?

A. I heard a noise, it sounded to me like an arc.

X Q. 65. One of those high musical arcs?

A. Not musical; on the contrary it was just a roar.

[fol. 2580] X Q. 66. You have referred several times to the presence of an inductive coupling; you did not testify in the main case, did you?

A. No, I had nothing to do with it.

X Q. 67. Would you be surprised that precisely that same inductive coupling was used in every experiment that was made in the Court by both sides in this case?

A. I do not know what the experiments were in that case; I have not read the record.

X Q. 68. Experiments for sending and receiving; would you be surprised?

A. I could not be surprised unless I knew what the tests were and I never read the record in that case.

X Q. 69. You said that by reason of that inductive coupling you were not sure that the oscillations of the three-element valve were what were causing the two-element valve to oscillate?

A. Substantially that.

X Q. 70. And you say that notwithstanding the fact that the two valves were oscillating at different rates?

A. There appeared to be beats.

X Q. 71. There were beats?

A. Yes.

X Q. 72. Then they were oscillating at different rates?

A. I think that they were oscillating at different rates from the presence of beats.

X Q. 73. Do you think it at all probable that oscillations at one rate would set up in the other valves oscillations of a different rate?

A. I think they might very well where the oscillations produced were of the very high frequencies, and the two circuits were slightly out of tune.

X Q. 74. Is it not true that this inductive coupling which we are talking about causes the receiving circuit to abstract energy from the transmitting circuit?

A. I think it undoubtedly causes a swapping of energy between the two circuits.

X Q. 75. But you would not admit that it would cause them to abstract energy?

A. Both abstract and return.

Re-direct examination.

By Mr. Darby, Jr.:

R. D. Q. 76. You did not state in your testimony, did you, that when the blue glow occurred in a two-electrode device that that spoiled the electrode device for future use, did you?

A. No; I did not intend to imply anything of that kind.

Mr. Bull: I did not intend to imply any thing of the kind either.

Mr. Darby, Jr.: I gathered from Mr. Bull's question that on using this two electrode device as a receiver that the inference was raised that Mr. Stone was testifying that the blue glow made it impossible for it to be used as a receiver.

Mr. Bull: I probably must apologize to my friend Mr. Darby. My scientific language was weak; my exact words were "put out of action"; I meant temporarily; I did not mean permanently.

Mr. Darby, Jr.: The file wrapper of the Fleming patent is in evidence as an exhibit, Exhibit W, in the main case. I would like also to use it in this case; do you desire it as a separate exhibit?

[fol. 2581] Mr. Bull: I think all the evidence in the main case, this is merely under a supplemental bill, all the other evidence is in this case.

The Court: There is no question about that. Let it be noted for convenience at this point that Exhibit W is the file wrapper.

Defendant's Proofs closed.

#### Plaintiff's Rebuttal Proofs

FRANK L. WATERMAN, recalled in rebuttal, testifies as follows:

Direct examination.

By Mr. Bull:

Q. 181. Mr. Waterman, you heard Professor Stone say that he believed the two-element valve could not operate as a generator of wireless waves unless the blue glow was present. Does that statement accord with your experience with these lamps?

A. It does not.

Q. 182. Are you prepared to demonstrate the operation of this two-element valve to the court as a generator in the absence of the blue glow?

A. We have a bulb there which last night generated without a blue glow and again this morning. I will be glad to try and see if we can do the same thing again.

Q. 183. You have heard Professor Stone state that the presence of the three-element valve in the receiving station might have been the cause of the oscillations of the two-element valve in the generating part of the apparatus. You also heard, I suppose, Professor Stone indicate a desire to see the two-element valve operate as a generator in circuits which did not include any three-element valve; is that true?

A. I did.

Q. 184. Are you prepared to demonstrate to the court the operation of the two-element valve as a generator in circuits which do not include any three-element valve?

A. I am, with some make-shift apparatus. I tried last night to get a commercial ticker, as it is called, without success, but by the use of a file and a wire scraped over it we break up the oscillations so that they may be received with the ordinary crystal detector, that simply being a rough way of imitating the action of the ticker.

Q. 185. Did you hear me in an informal way last evening after adjournment ask Professor Stone if he happened to have a ticker apparatus in his pocket and he said he did not?

A. I did.

Q. 186. Did you also hear Mr. Weagant ask him if he would be satisfied if the demonstration were made with an ordinary file?

A. I did.

Mr. Darby, Jr.: If your Honor please, as I recall it, that is not the way the question was put to Mr. Stone. There was a qualification that Mr. Bull has not expressed.

Mr. Bull: If you will correct me.

Mr. Darby, Jr.: Mr. Stone, as I recall, stated that the file could be used in the receiving circuit in place of the inter-[fol. 2582] rupter which he expressly mentioned could be used in the receiving circuit.

Mr. Bull: I did not know anything about that. We asked him if we could use a file.

Mr. Darby, Sr.: If new tests are going to be made we ought to have an opportunity to explain them.

Mr. Bull: I suppose you will have an opportunity to explain them, but you will understand these tests are not in any sense new tests, they are tests which your Honor almost indicated yesterday his desire to see.

The Court: Yes; I did want to see it.

Mr. Bull: And we have with such other apparatus as we could get together overnight, we are prepared to show the operation.

By Mr. Bull:

Q. 187. Will you proceed to make those demonstrations, and if you can do so make them both at one time.

A. If I can get Mr. Weagant to operate the apparatus; he is familiar with it.

The Court: Mr. Weagant, will you just state for the record what you are doing?

Mr. Weagant: In this test I am going to operate the two-element Fleming valve as a generator and I am going to use the same receiving set as was used yesterday with the exception that I employ a crystal detector to detect the oscillations.

Mr. Bull: In place of the three-element valve?

Mr. Weagant: In place of the three-element valve. These oscillations, being continuous oscillations, will not make any sound in the detector unless they are broken up in some way, or unless we have the beat as we had yesterday. So I am going to break these up at the transmitter here with a file and a light piece of wire connected across the points where the key is connected in the transmitter so that that merely disturbs the oscillations that are being generated in this coil, and there will be heard in the telephone receivers a scratching corresponding to my drawing the file across, and I shall show that that scratching stops if I stop the valve, or if I throw the tuner out of tune, showing that it is due to the oscillations.

The Witness: May I make a statement? Mr. Weagant used the expression "disturbing the oscillations". That I think is not quite an apt expression of what happens. We are merely replacing the sending key by the file which makes

the interruptions at such rapidity as will correspond to a rate that the ear can obtain.

Mr. Weagant: Yes.

The Witness: There is no blue glow in the valve, if your Honor will notice.

By Mr. Bull:

Q. 188. Will you explain, Mr. Waterman, the demonstration which has just been made?

A. The demonstration is identical with that which was made yesterday, with three exceptions. The valve which is [fol. 2583] being used is a different valve and one which on account of a higher vacuum, or some characteristic that we do not know, does not require the blue glow in order to oscillate. The detector employed is an ordinary crystal detector, and the three-element valve which was employed yesterday certainly not in operation, but it has been removed from the table entirely. I may say if I may interject that the sole reason why the valve was employed as the receiver was that I apprehended that the court would desire to receive oscillations with the two-element valve as well as transmit, and that was the convenient way of doing it, and furthermore, the set is a perfectly standard regular set without modification or alteration of any kind, and, further, was immediately and readily available to bring here.

The third difference is that the oscillations, or rather the signals sent, are broken up in this instance by what is in the parlance of the art called a chopper, the file and the wire imitating the chopper. That breaking up may be done at either the transmitting or the receiving station. I have had it put where it is for two reasons. In the first place, the circuit to which it is now connected is not one which is in any way associated with the battery. Hence, it cannot by any line of argument be reasoned that the operation of the wire over the file was affecting a battery current, and that it was not the valve that was operating. The second reason was that the coil is already tapped for the purpose while the commercial apparatus which we had is not tapped for that purpose, and to connect it across a whole coil would be apt to interfere with the tuning of the coil.

The operation was as follows: Upon the lighting of the filament by merely connecting the battery to it, the two-element valve started to oscillate. Those oscillations were re-

ceived by the receiving set and when Mr. Weagant rubbed the fine wire over the file, the court, as I assume, heard the peculiar, raspy noise which is characteristic of the ticker type of detector, and that noise ceased when Mr. Weagant disconnected the filament, and therefore stopped the valve from oscillating. The existence of that sound was evidence that the valve was producing radio oscillations.

The fact that the valve while producing those radio oscillations was not also producing the blue glow shows what I said yesterday, that the blue glow is not a necessary accompaniment of this oscillating condition and is merely an incident to the particular valve used. The valves of this wide spacing will commonly, not always, but often show this edge glow, as I have called it, and they do not go out of action, nor do they lose their sensitiveness until suddenly a change occurs which is visible to the eye when the blue glow becomes self-perpetuating, and suddenly fills the space, and then the bulb ceases to act entirely. This is equally true of three-element bulbs and is in no way peculiarly characteristic of two-element bulbs.

Q 189. Professor Stone intimated that the condition of the blue glow which is present in the two-element valve used yesterday was the condition which rendered it either inoperative as a detector or which decreased its efficiency as a detector. Is that statement in accordance with the facts [fol. 2584] as you observed them?

A. It is not. On the contrary, the valve as used yesterday with what little evidence of blue glow there was there, was undoubtedly in or approximately in its most efficient detector condition. As a matter of fact, that apparatus could be taken and used in the oscillating state as a receiver to receive distant signals and apparatus like that was used in the demonstration to me by Mr. Weagant when he received European signals. The signals of Nauen in Germany, and as I think Professor Stone himself said yesterday, when we make beats we do not thereby detect, we merely produce something that can be detected. The beats, as Mr. Weagant said a few moments ago, themselves cannot be heard. We have to have a detecting function and that detecting function is performed by the bulb at the same time. Hence, in order that the bulb may be used, as Professor Stone used it, for example, yesterday when he listened to signals sent from the nominal receiving end, the detecting function has to be there in order that one may

receive at the time when the bulb is oscillating, and hence this oscillating condition, whether it is accompanied by this blue glow or not, not only does not destroy the detector function, nor, so far as my observation goes, impairs it in any way. On the contrary, it increases the sensitiveness of the bulb always as a detector.

When, of course, the blue glow passes the point where it is tolerable then suddenly both the detecting and the oscillating function ceases.

Q. 190. Then you distinguish between such a blue appearance which was exhibited in the two-element bulb yesterday and the true blue glow which puts a detector out of action temporarily?

A. There is a very marked distinction between them.

Q. 191. From what you have said I gather that you do not agree with Professor Stone's statement that this apparatus with the two-element valve as it stands has no commercial utility whatsoever.

A. I do disagree, and on the contrary that apparatus just as it stands when put on the big antenna could be used to receive signals from across the water.

Q. 192. Professor Stone has stated that the presence of the inductive coupling between the generating and the receiving ends of this apparatus is perhaps responsible for the fact that the two-element valve acted as a generator when the three-element valve was being used as a receiver. Will you state your views on that point?

A. I disagree with Professor Stone for three reasons. First, this coupling coil merely replaces the antenna that would ordinarily be employed in a full practical apparatus, and it is the thing which is universally used for laboratory or indoor tests. It is the same means of coupling that was used in all analogous tests in the main case and its substantial propriety was recognized by both sides throughout the case and is recognized generally in the art because it is universally employed.

The second reason why I disagree with Professor Stone is that that coil is not in any way connected with the valve that was oscillating. On the contrary, that coil connects with the primary coil in the receiving set and that is only loosely [fol. 2585] coupled to the circuit to which ultimately the three-element valve is connected. Hence it is only a feeble energy in any case which can flow in that circuit from the

valve, and it is not of a large and controlling order as might be inferred from what Professor Stone said.

In the second place, such oscillating energy as flows in that circuit, due to the oscillations of the valve, is of a different frequency from that being generated by the two-element valve acting as generator, and necessarily so, because it is the heterodyning frequency which must differ from the frequency being generated in order that beats may be produced.

Now, it is only by concurrence of impulsing that an effect such as Professor Stone referred to can be produced. The resonant effect to which he refers implies that each time an oscillation occurs an impulse is delivered strictly in time. In contradistinction to this the essence of the beat method is that that thing shall not occur, but that that shall occur successively in time and out of time so that every beat which occurs out of time tends to stop the oscillation, while every beat which occurs in time may tend to an equal amount to undue that stopping force. The net result, therefore, is zero, so far as any effect of this different frequency current on the circuit is concerned.

One aspect of the coupling that I neglected to refer to a moment ago is that the function of that coupling is to withdraw energy; that is what it is there for. Professor Stone preferred to say that they swapped energies. The energy, however, which was withdrawn was the energy produced by the two-element oscillating bulb, withdrawn at its own frequency, and therefore tended to stop the bulb from oscillating. The energy which, if we adopt Professor Stone's testimony, was swapped, was energy of a different frequency which did not tend either to stop or to make it go, the total effect was necessarily zero because of the beat phenomenon which it is its purpose to produce.

Q. 193. The circuit which is used in this demonstration apparatus has been criticised, and I am referring now to the circuit used both yesterday and today; what circuit is that; where does that come from?

A. That circuit was suggested for this purpose by myself because it is the circuit of the DeForest apparatus that was at issue in the main case.

Q. 194. The P N circuit?

A. The P N circuit, and I supposed that that had been settled, and I just had it on that account. Also a further reason was that it was a circuit that had been dealt with

at such great length that its characteristics were made very clear. No one told me to use it, or said anything about it. I selected it myself and I am solely responsible for it.

Q. 195. As I understand it, that is the P N circuit with an impedance coil and a key added to it?

A. Yes. That is true, but the original circuit from which the P N circuit is derived had a choking coil in it. That designation P N is merely a DeForest Company's trade name. The circuit is an old well known circuit which was devised by Marconi and has been known since many years before the bulbs came into the art at all.

[fol. 2586] Q. 196. I think you referred to the Marconi patent to which you are now referring in your direct examination. To make the matter clear, I will ask if you refer to the circuit of the Marconi patent No. 627,650 which is printed at page 2669 of the printed transcript of record in this case?

A. Yes; that is what I referred to, and the iron coil, as I said, was present, as is indicated as C1, C2 in this circuit, so that in its original form the circuit included that coil.

Q. 197. Professor Stone has said that we have not here a case of true reversibility because in using this two-element valve as a generator we must change the circuits from those in which we use it as a detector; is that correct?

A. It is not. If it is going to be called reversibility at all it is certainly true reversibility because the same circuit in the same condition without alteration and adjustment, or touching it in any way, could be used to send and receive, and it was so used in this room yesterday afternoon.

Q. 198. In other words, our offer to the court was to use that same circuit in the same identical condition as a receiving circuit after we demonstrated to the court the use of it as generator circuit?

A. Yes.

Q. 199. And there was to be no alteration in the circuit whatsoever?

A. There was to be no alteration whatsoever. Furthermore, it is not necessary to call it reversibility because that action is something that occurs while you are using it as a detector, and it only requires that sort of signal known as undamped oscillation to immediately give you the beat reception whether you are looking for it or not, just as in the case where my using the three-element valve got the peculiar

characteristic of the oscillated signal, so the same thing occurs here in the use of this two-element valve.

Q. 200. In other words, as I understand you, when you are using it as a detector with the beat note the thing is generating just as truly and exactly the same way as when you are using it as a generator?

A. Yes. It takes no different manipulation of the apparatus, and if the valve is one that tends to do that, it just does it automatically.

Q. 201. It is just as truly a generator when you are using it as a beat detector as it is when you are using it as a generator?

A. Absolutely.

Cross-examination.

By Mr. Darby, Jr.:

XQ. 202. You recall Mr. Stone's suggestion of yesterday, do you not, of using a ticker or an interrupter in the receiving circuit?

A. Yes.

XQ. 203. Do you recall Mr. Weagant suggesting, or you suggesting, that you might use a file in place of it?

A. Yes.

XQ. 204. In this demonstration which you are giving now you have not done that, have you?

A. No, but we will if you want us to. The only reason it is not done is what I explained in my last answer.

XQ. 205. The principal one being you were afraid we would raise the point that the voltage was causing, or rather the current supply was causing, the click to be heard in the telephone receivers?

A. That was one reason, yes.

[fol. 2587] XQ. 206. You say you would be willing to connect it in the receiving circuit?

A. Yes.

XQ. 207. May I ask you to do it?

A. We have not the taps to do it to the same advantage, therefore it would not tune. This coil, I may say, has the special tap put in to put the sending key across. It is tapped in such a way as not to interfere with the tuning, whereas we have not this provision on this ticker.

By the Court:

Q. 208. Will this take long?

A. It might take anywhere from one minute to five or ten.

Mr. Bull: Do you want to go on with the cross-examination while they are getting that ready?

Mr. Darby, Jr.: I will be glad to do it, except I may have some cross-examination on that.

The Court: Yes.

By Mr. Darby, Jr.:

X Q. 209 Has there been any change in the amount of voltage that was employed for this demonstration today from the amount of voltage that was employed in the demonstration of yesterday?

A. I assume so; that always follows when you change valves. You always do that because you take the voltage that brings the particular valve you are using to the right point on its characteristic curve.

X Q. 210. Did you find out the approximate amount of change?

A. Yes.

Mr. Darby, Jr.: I would also like you to get that information for me; I presume that can be gotten, Mr. Weagant?

Mr. Bull: That is right; Mr. Weagant will get that.

The Witness: As I said yesterday, these valves may take anywhere from 25 to 200 volts. The amount to use is the amount that the particular valve requires.

By Mr. Bull:

Q. 211. We had some experiments relating to that, it seems to me, in the main case.

The Witness: I think we had a number.

By Mr. Darby, Jr.:

X Q. 212. Are you familiar with the use of grid oscillion?

A. I am familiar with the ordinary three-element bulbs. I have not used the large bulbs which I believe DeForest calls the oscillion.

X Q. 213. You are familiar with its use as an oscillation generator?

A. Yes.

X Q. 214. Are you familiar with its use as an oscillation generator for transmission purposes?

A. Yes, but not the bulb actually made by the DeForest Company.

X Q. 215. One of that general form including those elements in the same arrangement?

A. Yes.

X Q. 216. What voltage did you use in connection with that device, that bulb?

A. I have seen them work all the way from five or six volts up to 500 or 600, I judge; I cannot tell.

[fol. 2588] X Q. 217. In generation?

A. Yes.

X Q. 218. Of electrical oscillations for transmission purposes?

A. When you are using them for transmission purposes you choose a bulb on which you can put a high voltage.

X Q. 219. What is the voltage you generally employ?

A. I cannot say as to that, but my recollection is that on the one big bulb which I have used, which is a General Electric bulb, we used 500 or 600; it may have been 1,000, I am not certain.

X Q. 220. You have no cause to disagree with my statement, then, that the voltage generally employed with those bulbs runs from 200 to 1,500 volts?

A. That agrees with my understanding. You make a bulb with a spacing so that it will take that voltage.

Mr. Bull: Mr. Weagant is ready with his tests.

Mr. Weagant: Do you hear the scratching, your Honor?

The Court: Yes. I heard it. When the Fleming valve is put out of action the scratching noise stops. Now I hear a very faint scratching. Now the scratching is very distinct.

Mr. Bull: In the meantime Mr. Weagant was adjusting the apparatus.

The Court: Now it is thoroughly distinct.

The Witness: Will your Honor note there is no blue glow in the valve? You can get that more critically if you stand where the coil cuts the light of the filament out of your eye.

The Court: Yes, there is no blue glow as far as I can see.

The Witness: Will you please measure the voltage which you are using?

Mr. Weagant: Yes.

By Mr. Bull:

Q. 221. Will you explain the demonstration which has been made?

A. The demonstration requested by Mr. Darby has just been made. The same two-element valve was caused to send oscillations as before, but in this instance the file which was used to interrupt the oscillations was connected as requested to the receiver and the file alone was used as a ticker, as is customary in ordinary receiving practice where the ticker is employed. The bulb oscillated in this test as in the former without the production of any blue glow.

I find that the voltage employed, the measurement of which was requested by Mr. Darby, is 110 volts.

By Mr. Darby, Jr.:

X Q. 222. Referring to the Fleming disclosure in the Fleming patent, and confining yourself particularly to the disclosure in Fig. 1: Under your definition of the reversibility of function, or the phenomenon of reversibility, in your opinion would that be capable of reversible action?

Mr. Bull: I object to that; I have not asked this witness anything about the Fleming patent.

The Court: I will allow it.

[fol. 2589] A. Yes, provided that the galvanometer used is either shunted by a condenser to give a path for the oscillatory currents, or that it has sufficient capacity of itself in its own winding, as it probably would have. I assume, of course, that the question contemplates the use of the battery to provide the local source of energy.

X Q. 223. In this last demonstration that was made, Mr. Waterman, were parts of the same battery used to excite the crystal detector at the receiver and for exciting the valve at the transmitting; I do not refer to the last test, I mean the test before the last?

A. No. The crystal receiver was not connected to the battery at all.

X Q. 224. May I ask why you did not use the simple Fleming circuits as disclosed by the Fleming patent for the purposes of these tests?

A. I have already said that without giving the matter any particular thought I told Mr. Weagant to arrange his apparatus to correspond exactly to the P N circuit which was already demonstrated on various occasions before the court. I had no other reason.

X Q. 225. You had absolutely no other reason?

A. I had no other reason, no. As a matter of fact, my experience is the valve oscillates either in that circuit, or in the P N circuit, but I certainly had no reason for trying to dodge that circuit.

#### Testimony Closed

To be argued March 24, 1919, at 2:30 P. M.  
Briefs to be submitted also.

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New York, May 16, 1919.

#### Trial Resumed

Present: J. Edgar Bull, Esq., *Attorney for Plaintiff*; Samuel J. Darby, Esq., and Samuel J. Darby, Jr., Esq., *Attorneys for Defendant*.

Before: Hon. Julius M. Mayer, Judge.

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FRANK L. WATERMAN, a witness on behalf of the plaintiff, recalled, further testifies as follows:

#### Redirect examination.

By Mr. Bull:

R. D. Q. 226. Mr. Waterman, at the last session you were asked the following questions and made the following answers (I read from page 58 of the record): X Q. 155: "I will now ask you a few questions in connection with the circuits employed along the lines of the questions asked by his Honor. It is so obvious that I do not believe it is necessary to emphasize it. The circuit employed in connection with the Fleming valve as a generator is nowhere disclosed in the Fleming patent?"

A. I will be glad to operate it in that circuit if you would like."

[fol. 2590] Then, at page 119, on cross-examination you were asked, X Q. 222: "Referring to the Fleming disclosure in the Fleming patent and confining yourself particularly to the disclosure in Fig. 1, under your definition of the reversibility of function, or the phenomenon of reversibility, in your opinion would that be capable of reversible action?"

A. Yes, provided that the galvanometer used is either shunted by a condenser to give a path for the oscillatory currents, or that it has sufficient capacity of itself in its own winding as it probably would have. I assume, of course, that the question contemplates the use of the battery to provide the local source of energy."

Now, are you prepared to make the demonstration which you expressed your willingness to make at that time?

Mr. Darby: If you Honor please, I submit this is not what we are here today for; that circuit they are going to show is substantially the identical circuit they showed at the other test, and is not the Fleming patent. I understand we are here today for a demonstration of this valve as an oscillator on the circuit of the Fleming patent. If it is merely a repetition of what was done before it is useless, and I think it appears on its face that is what it is, a repetition of what was done before.

Mr. Bull: We are getting to that, your Honor. I will show it is not a repetition of what was done before. The other was PN circuit. This is Fleming circuit. The other was a divided circuit we were talking about all through that case; this is a single circuit and not a divided circuit. It is the Fleming as distinguished from the PN circuit.

Will you please make the demonstration? (Demonstration is made.)

The Court: I hear a scratching noise as Mr. Weagant draws a fine wire across the file.

Mr. Weagant: You will notice you cannot hear that scratching device when the valve is stopped.

The Court: That is true.

Mr. Weagant: The valve is no longer lighted.

The Court: With the valve lighted I hear it again.

R. D. Q. 227. Will you please explain the experimental apparatus which has thus been demonstrated before the Court?

A. May I have the diagram, please? The experimental apparatus which is demonstrated to the Court is the same as that which was employed before with the following exceptions: The inductance coil having the iron coil and the condenser corresponding to what was removed from the circuit, and the rest of the apparatus has been rearranged so that instead of being a divided or PN circuit it is a simple series circuit such as is shown in the Fleming patent with the addition, as I stated in my former testimony, of a condenser, that is to say, the condenser C which was in the former apparatus has been preserved. The apparatus therefore is identically that of the Fleming patent as shown at the left hand side of the diagram which I produce, with the added condenser which I said would be necessary. The telephone apparatus and the coils not furnishing sufficient capacity within themselves, and that condenser being the usual accompaniment of a circuit. The actual circuit connections are shown at the right hand of the diagram where the receiving apparatus is shown. The file is used on a receiver instead of the heterodyne, because in the former tests the use of the heterodyne was objected to [fol. 2591] and the file substituted for limited tests thereon, and therefore the file has been preserved.

The Court: That is, without the condenser, as I understand it, it won't work?

A. Can you make it work without the condenser, Mr. Weagant?

Mr. Weagant: I am not sure of that. I do not think I can with this particular apparatus.

The Witness: The condenser is necessary to provide a path for the high frequency oscillations.

R. D. Q. 228. Will you point out in detail to his Honor the difference between the circuit arrangement the other day and the circuit arrangement today, because counsel has contended they are the same.

A. May I have the exhibit volume of the record? There is a diagram in there which just exactly does that. I refer to Plaintiff's Exhibit 64, found in the transcript of record, page 2455, in Marconi against DeForest.

Mr. Bull: That is this case?

The Court: Yes, this case.

A. (continuing): The circuit which was demonstrated before is that marked "DeForest Fig. 1" and which is found at the bottom of this Exhibit 64 sheet. The characteristic of this circuit is that what waves are received are impressed upon the valve used as a detector by means of one circuit through a condenser. The effect produced in the detector is recorded or made evident in a circular circuit.

Now, in the Fleming circuit, which is that shown at the top of the Exhibit 64, both of those functions are combined in one circuit. The high frequency oscillations received are impressed upon the valve in that circuit and the effect produced is registered in that same circuit, whereas in the lower figure the oscillations are registered through the upper one of the two circuits which the lower figure shows, while the effect produced is indicated in the lower one of the two circuits. That is the difference between the P N circuit and the circuit of the Fleming patent. Both of these are circuits which were shown simultaneously in Marconi Patent 627,650, and they are interchangeable circuits, that being so ever since. Their difference is in all cases we have in one instance the impression of the oscillations through a separate circuit, whereas in the simpler form of circuit which Fleming happens to show, both functions are performed in one circuit.

R. D. Q. 229. Now then, as I understand it, the apparatus which you demonstrated today is exactly like that marked "Fleming" in Plaintiff's Exhibit 64, at page 2455 of the transcript of record?

A. Yes.

R. D. Q. 230. And what you demonstrated before was like that marked "DeForest Fig. 1" in the same exhibit?

A. That is correct.

The Court: Let me ask you this, to refresh my memory: At the time of the Fleming patent was the use of the condenser as you used it today familiar to the art?

The Witness: Oh, yes, it had been familiar to the art at least three years; I think four.

[fol. 2592] R. D. Q. 231. Are you prepared to now confirm those statements by reference to literature?

A. Yes. If I may I will refer also to Plaintiff's Exhibit 12, which is the original diagram which I used in comparing the DeForest alleged infringing device with the Fleming patent. The Court will see that the same difference exists

as that pointed out by reference to Exhibit 64. In this instance the antenna happens to be shown in that issue and the wireless wave received through its effect on the coil M impresses the energy on the coil K, which is impressed by that circuit upon the valve, and what happens as a result thereof is indicated by the instrument I in that same circuit, whereas in the PX circuit the circuit which I used for demonstrating also if the valve is an oscillator, at the last hearing, we have the energy which is transported to the coil K impressed on one circuit and its effect indicated in the instrument I in another circuit. And that is the difference between those two circuits.

Now, in the circuit which I am using today the energy of the oscillation takes place in this circuit; that oscillation is tuned in the same circuit upon the valve. What happens here in this oscillating state apparently is that a disturbance produced an effect which is recorded in a change of energy here in the circuit. That change of itself is impressed again on the valve and another oscillation occurs. Each wave thus repeats. That is the way in which the oscillation apparently takes place and is preserved.

The Court: Was the tuning condenser shown in what we have often spoken of as the old Marconi circuit, referring now to Letters Patent 627,650, to Marconi?

The Witness: No, that tuning condenser in this instance is not shown.

The Court: Now, Mr. Bull suggested that we show by authority or literature this use of the condenser was known in the art at the time of the Fleming patent.

The Witness: Mr. Pickard, in this record, pointed it out at pages 336-337 of the record, and I have here quotation from his testimony which refers to Stone Patent 714,756 which I believe was in that record.

Mr. Bull: Does your Honor want that to be read in?

The Court: I think I would read it in.

The Witness: I read from page 337, folio 1010 of the record:

"In the Stone system of 1900 (Chart 35) a tune import circuit is used in which there is two condensers. One is shown as the upper condenser, which I will mark C<sup>1</sup> in red pencil on the chart, and the other condenser is the lower condenser, which I will mark C<sup>2</sup> also in red pencil on the chart. These two condensers perform different functions. One is a

tuning condenser, that is to say it has to do with the tuning of the circuit. The other is what is often in this art called a blocking condenser; that is to prevent the flow of current from Battery B over into this secondary circuit."

Referring to the Stone patent mentioned, which as appears from page 336, folio 1008, is Stone Patent 714,756, I refer to Fig. 6 thereof. In this Fig. 6 this tuning condenser is shown at C and the stopping condenser at C'. The condenser which I have employed is the condenser C, that is the tuning condenser, and it is connected in the same relation in the circuit as is shown in this Fig. 6 of the Stone patent, namely, effectively across this valve or detector element.

The use of this condenser was disclosed by Marconi at a very early date in his Journal of the Society of Arts paper, of May 17, 1901, and it is also disclosed in his patent which I think is in evidence in this record, 763,772, Marconi Tuning Patent as it is generally called. I refer here to Fig. 2, where the tuning condenser H<sup>1</sup> is shown in the same relation across the detector.

R. D. Q. 232. When was that application filed?

A. November 10, 1900. Referring to the Marconi Journal of the Society of Arts paper, I refer to page 511, near the top of the first column.

R. D. Q. 233. What is the date of that paper?

A. May 17, 1901, where Marconi says: "In order to make the tuning more moderate I place an adjustable condenser across the coherer in Fig. 9." Another instance is in Fessenden Patent 706,735, where Fessenden places a condenser in shunt to a galvanometer detector, the condenser being indicated at 19 in Fig. 1 for the purpose of permitting the free passage of oscillations and controlling the tuning. In DeForest Patent 730,246, dated June 9, 1903, the same arrangement is shown in a great many different forms. I will refer to Fig. 26, where the condenser K is shown as a tuning element in the secondary circuit. The shoemaker patent, 711,131, dated October 14, 1902, shows such arrangement in Figs. 3, 4 and 5.

I made note that Fleming in his testimony in this case, at page 141 of the record, referred to the use of a condenser. Fleming says, referring to page 141, folio 422, of the record:

"It is of course an advantage that the receiving circuit should be tuned to the wave frequency and to the transmitter frequency. The receiver circuit therefore usually contains inductance and capacity. In the simple diagram of receiving circuit figured in Fig. 1 of the specification of my U. S. Patent No. 803,684, the circuit in which the oscillation valve is placed is shown as a simple aperiodic circuit. The subject matter of that patent is, however, the nature of the wave detector itself and not of the circuits to which it is attached. It makes no manner of difference to the mode of operation of this thermionic detector in itself, whether it is connected to an aperiodic or to a tuned receiving circuit."

Professor Fleming here calls the circuit aperiodic, that is, a circuit which is incapable of sustaining oscillations. That is on the assumption that the apparatus itself does not furnish sufficient capacity, but sometimes it will. In this instance the condenser has been found apparently necessary although it oscillated with the condenser at zero, which means that the condenser has had little or no effect.

Mr. Bull: I offer in evidence the Shoemaker Patent 711,131, the DeForest Patent 730,246, the Fessenden Patent 706,735, and the Marconi Patent 763,772.

I also offer in evidence the Sketch produced by the witness, illustrating the arrangement of the circuits in the apparatus demonstrated today. The patents are marked with appropriate titles, and the Sketch is marked Plaintiff's Exhibit Waterman's Sketch, May 16, 1919.

[fol. 2594] Mr. Darby: I want to enter objection to the offer in evidence of the patents, for the reason that it is not timely, and irrelevant, immaterial, and further, it is contrary to what we understand the purpose of this demonstration, and we are therefore taken by surprise and we certainly would be entitled to rebut any evidence given in respect to these.

The Court: I will receive them and if you want to study them over, you may.

Mr. Darby: I would like to say this, your Honor, that so far we have not been favored by Mr. Bull with the data we asked for and which he promised at the hearing the other day.

The Court: I receive these in evidence in view of my own inquiry as to the state of the art at the time in regard to this

matter of the tuning condenser. Of course, if you desire an opportunity to have some time to go into that, you may have it.

Mr. Darby: It may be that the cross-examination of Mr. Waterman will supply what we want. I do not know about that. I want to reserve the point.

The Court: All right; proceed.

R. D. Q. 234. Have you any other patents illustrating the same point?

A. I have a considerable number of other patents to Stone. These are 714,831, dated December 2, 1902, where I refer for example to Fig. 5.

R. D. Q. 235. Which shows tuning condenser where?

A. It shows tuning condenser at C.

R. D. Q. 236. Now, if you will, just go through each one of those, saying that.

A. Stone Patent 716,136, dated December 16, 1902, where the condenser is shown at C in the figure.

Stone Patent 717,514, dated December 30, 1902, where the condenser is shown at C in Fig. 3.

Stone Patent 725,634, dated April 14, 1903, where the tuning condenser is shown at C in Fig. 9.

Stone Patent 725,635, April 14, 1903, where the condenser is shown at C in Fig. 2.

Stone Patent 725,636, where the condenser is shown at C, in Fig. 3.

In citing these figures I do not cite them as the only instances where such tuning condenser is shown in these patents but merely take a figure as illustrative.

R. D. Q. 237. Mr. Waterman, can you now demonstrate the oscillation of this apparatus with the condenser disconnected?

(Witness demonstrates.)

The Court: I hear a scratch on the file distinctly.

The Witness: The condenser is now disconnected.

Mr. Bull: That is all.

Recross examination.

By Mr. Darby, Jr.:

R. X Q. 238. I understood you to say, Mr. Waterman, that Fleming, the inventor, states that the circuit of his path is

aperiodic and consequently it is not oscillatory, is that correct?

A. I quoted what he said.

R. X Q. 239. That is correct substantially?

A. I may say whether such a circuit is or is not aperiodic [fol. 2595] depends upon the apparatus that is used. If the apparatus itself has sufficient capacity and sufficient lower resistance then it is oscillatory, and that proves to be the case here.

R. X Q. 240. That is merely incidental though, is it not?

A. That is usual. As a matter of fact such circuits used to be called aperiodic, but it is the usual thing to find them oscillatory, but it is not necessarily true that even if oscillatory they will have energy storage capacity enough to sustain oscillations in the valve because such oscillations imply that the circuit shall have some energy storage capacity that is appreciable as compared to the sensitiveness of the valve.

R. X Q. 241. The oscillations produced by this valve without the condenser are not of sufficient strength for any commercial purpose of transmission, are they?

A. In that particular apparatus probably not, no. It was not made for that purpose. That valve is a very small valve, made for detector purposes.

P. X Q. 242. Then you have taken what Fleming has called an aperiodic circuit and have made it an oscillatory circuit by merely controlling the capacity and inductance of the circuit, is that true, or have you added something in addition?

A. I have neither added anything nor have I controlled the constants of the circuit. The coil is just an ordinary wireless coil, such as has always been used; and an ordinary telephone is substituted for the galvanometer which Fleming shows.

R. X Q. 243. Can you make this valve oscillatory without the B Battery?

A. Certainly not.

R. X Q. 244. Is the B Battery shown in the Fleming Patent?

A. No, the B Battery is not shown in the Fleming patent, but that I assume has been sufficiently thrashed out in this case.

R. X Q. 245. Not for the purpose of transmission. Then you have in fact added an element to the Fleming circuit which is not shown in the patent?

A. Absolutely, I have added the battery. That I said in my former testimony.

Re-redirect examination.

By Mr. Bull:

R. R. D. Q. 246. Did you ever suggest, Mr. Waterman that you could with one of these valves generate current if you did not have any current to oscillate?

A. I certainly did not.

R. R. D. Q. 247. Or cause oscillations, rather, if you did not have any current to oscillate?

A. I certainly did not. There must be a source of energy. There must be a cold wire energy when you generate energy in your electric wires.

R. R. D. Q. 248. And that is what you specifically pointed out in answer to Mr. Darby's question at the last hearing, when he asked you if this circuit could be made to generate oscillations?

A. I did.

Re-recross examination.

By Mr. Darby, Jr.:

R. R. X Q. 249. Is not the A Battery a source of energy for reception purposes?

A. For heating the filament phone only.

Mr. Darby, Jr.: For the sake of the record, I would like to have it noted that the B Battery employed is 150 volts.

R. R. X Q. 250. Are these the same valves, do you know, that were used at the last demonstration, or have they been constructed since that time?

A. Well, I know the valves that were used in the last demonstration are here.

[fol. 2596] R. R. X Q. 251. Are here?

A. Are here also; all; which one is used I do not know, but I do know, that is, I understand, that they have not been constructed since the last demonstration.

Mr. Darby, Jr.: Mr. Weagant, is this particular valve that was employed in the demonstration constructed since the last demonstration, or has it been altered in any way?

Mr. Weagant: No. They are all of the same lot. They were made two or three years ago.

The Court: Mr. Waterman seems to think even more than that.

The Witness: It is so long ago that I really forget just when.

The Court: They were just that lot of valves which you spoke of before; they were taken from what you have?

Mr. Weagant: Yes.

Mr. Darby, Jr.: I would like to ask Mr. Weagant; Mr. Weagant can probably tell us, if this particular valve is one that was refitted for detector purposes?

Mr. Weagant: I can say that it is not.

Mr. Darby, Jr.: It is not one that was refitted for detector purposes?

Mr. Weagant: It is not.

The Witness: There is one thing I think might appear on the record in connection with the fact that the voltage is 150, and that is this valve is one of very long spacing, fully  $\frac{3}{4}$  of an inch between the nearest point of the filament and the plate, and as I explained at the last hearing, the voltage which is employed could not fog; and the lot of valves which Mr. Weagant and I were experimenting on when this was made was with that spacing.

Mr. Darby, Jr.: If your Honor please, I do not like to burden you with continued demonstrations or anything of that nature, but what I did want to show was this, and I do not know whether you would be interested in it or not, and if you are not interested in it we will drop it, but the Fleming patent calls for a valve containing a very high degree of vacuum. I am prepared to demonstrate if they keep this valve in the condition it is now that that valve is a low vacuum valve, and that if it is made of a high vacuum valve they cannot make it oscillate. It is true that it is a question of degree between the high and the low vacuum, but Fleming has put himself on record what he meant by high vacuum. He has done so again recently, in 1916, what he meant by high vacuum as used in his patent at that time.

Mr. Bull: We do not care what he meant by it.

The Court: Under well settled principles of the patent law, he is not the one to whom we have to refer.

Mr. Darby, Jr.: What was meant by him at the time the patent was drawn up?

The Court: It is a simple and well settled proposition that we do not get the man's own construction of his patent. If you did, why, every man who patented something would be sure to have a valid patent.

Mr. Darby, Jr.: Well, you will recall there were some letters offered by the plaintiff as exhibits on this question.

[Feb. 2597] Mr. Darby: It is not a question of construction of the patent, it is a question of the physical structure.

The Court: I do not see that we gain anything by that at all.

Mr. Darby, Jr.: Except this, in the one instance they have got a high vacuum which is of high resistance across that path and in the other instance to have it control it at all they have to have a low resistance across that path.

A lot has been said about the condenser. We did not bring that up.

Mr. Bull: Excuse me, your father did if you did not.

Mr. Darby, Jr.: On the condenser?

Mr. Bull: Yes, the very first thing you said was about the condenser to me.

Mr. Darby, Jr.: In the trial?

Mr. Bull: Off the record.

Mr. Darby, Jr.: I mean on the record. I have not brought up the question of condenser at all because that is not the point on which we are relying. We accepted at the start Mr. Waterman's statement when the distribution capacity is sufficient you could make it oscillate provided you put in a B Battery and provided you have a gas-less medium in there or other low degree vacuum absolutely contrary to what is called for by the Fleming patent, and I think the B Battery situation has taken care of itself.

We are prepared to make any test to show that with the degree of vacuum called for by the Fleming patent they could not make it oscillate even with the B Battery.

Mr. Bull: As to the degree of vacuation, I do not see what it has got to do with it, but I am prepared by Mr. Waterman to have him state what kind of vacuum that has got in it, if he knows.

The Court: Do you know, Mr. Waterman?

The Witness: I know, from the way it behaved.

The Court: What is your judgment?

The Witness: The filament was run during these adjustments at temperatures that are exceedingly high for even a tungsten filament, which temperatures are enormously higher than the carbon filament which Fleming's could have been run at. It had 150 volts on the space, and under none of these conditions was there a blue glow. That indicates a vacuum which is of very high order, probably of an order very much superior to anything that could have been obtained as a matter of physical fact in Fleming's day, so that it probably has not only Fleming's vacuum, but one very much higher than Fleming could have gotten.

Mr. Darby, Jr.: We are prepared to make an accurate measurement of that bulb, and with regard to its being of higher vacuum, it is a physical and scientific impossibility.

I am informed by engineers that valve would not oscillate with 150 volts; it is a scientific impossibility, if it has a high vacuum.

The Court: I think your proposition is very simple. You have here the hot and cold electro device of Edison?

Mr. Darby, Jr.: Yes, sir. Now, in the course of description Fleming refers to a high vacuum, which is a relative [fol. 2598] term. Now they take one of these Edison electric bulbs and in connection originally with the detector\* Fleming made this invention by demonstrating that he could use this Edison device in certain relations and make the thing detect radio signals. Now then, they take for all practical purposes the same thing and insist that it can generate oscillations as well as detect. I do not think they insisted all of them could do it; about one per cent.

Mr. Bull: No; I pointed out at the last argument it was absolutely not so at all.

Mr. Darby, Jr.: He further testified he can not take any one of these bulbs, build one, and be sure it is going to oscillate.

The Court: You mean in the relation shown strictly in the Fleming patent?

Mr. Darby, Jr.: Yes, sir. That is, it is an idiosyncrasy.

The Court: If this experiment is true they have demonstrated that it can be done.

Mr. Darby, Jr.: In certain circuits, yes.

Mr. Darby: 150 volts is comparable with the voltage employed for different purposes.

The Court: My point is, that whatever the controversy is and the points of difference between the litigants, that the controversy is well exposed. I do not see that I will gain anything by an experiment which takes different bulbs and maybe gets a lesser result. Now, probably they would try 20 bulbs and maybe two of them would do the thing without the condenser and the 18 might not, for all I know.

Mr. Darby, Jr.: For the sake of the record, the experiment I wanted to make is this: Take any bulk and show where it will oscillate and show where it stops to operate. As I stated at the outset, you may not be interested.

The Court: Revolving on the question of high vacuum?

Mr. Darby, Jr.: Yes. What is high vacuum? Using Fleming's own statement, even of 1916, and even today when a man skilled in the art saw and read the words "high vacuum", what would he understand? The high vacuum obtainable, and then see what was the highest vacuum obtainable at that time, which is pretty nearly the same degree they can get now. I think that shows pretty nearly in the art.

Mr. Bull: You were not in the main case or you would have heard your brother counsel argue there——

The Court: Brother father counsel.

Mr. Bull: Yes. That the vacuum of the Fleming patent was not any vacuum at all; it was all gas; they said it was full of gas.

The Court: In the main case the vacuum referred to was the vacuum of the order of an incandescent electric lamp. Now that being so and the case having been there fully considered both by this court and the Circuit Court of Appeals, upon that together with other matters, I do not see that on this question we gain anything at all by further experiment on the line indicated by you.

Mr. Darby: Could we, if your Honor please, along that line ascertain just what the vacuum is in the lamp that was tested?

The Court: I do not see any objection to that. Can you measure that now, or do you have instrumentalities?

[fol. 2599] Mr. Darby, Jr.: We have to have instrumentalities to measure it. I think if Mr. Bull and I can agree on some mutual third party to take charge of the valve and have it tested, we can have it done that way.

The Court: What kind of test do you have to make?

Mr. Bull: Mr. Weagant says they can never agree as to what the result was after it was measured; in other words there is no accurate method of determining from the outside what vacuum there is on the inside.

The Court: Let me ask you this, Mr. Waterman: this, as I understand, is a normal type of an incandescent lamp? Is that so?

The Witness: Absolutely.

The Court: And is fundamentally known and at all times has been known in the art as such?

The Witness: Yes.

The Court: With a vacuum?

The Witness: Yes, and the vacuum we are using is high for incandescent lamps; that is, they were of the best, and we tested the highest point voltage they would stand without beginning to produce a blue bulb and with the high temperature filament.

The Court: I do not see that we can gain anything, Mr. Darby.

Mr. Darby, Jr.: All right, s.r. Are we to file briefs or memoranda?

The Court: Yes, I wish you would give me a memorandum practically on two points. I mean I do not confine you to that; if there is anything occurs to either of you you may add.

Point No. 1: Whether the use of the Battery B current in any manner affects the proposition of law which the plaintiff advances, that is to say, whether the use of that Battery B device, which was not shown in the Fleming patent, has any legal effect upon the comprehensiveness of the patent. Do you understand the point?

Mr. Darby, Jr.: Yes, sir.

The Court: Now then, the second point is: Assume for the purpose of the argument that the oscillating qualities of the Fleming valve when shown in the Fleming circuit without the condenser and even with the Battery B current is only occasionally perceptive, and assume further that the Fleming valve when used in the old Marconi circuit or in any other relation of circuits then known to the art does in point of fact clearly and plainly oscillate, then as applied to the oscillating qualities as distinguished from the detecting ones, may the plaintiff in seeking to have its present construction of the patent obtain, have the advantage of the situation of the Fleming valve with existing circuits

known to the art other than the circuit shown in the Fleming patent? Do you understand?

Mr. Bull: I think we do.

The Court: In other words, to explain that a little, when Fleming made this invention, which I held and the Circuit Court of Appeals sustained me, was a very marked advantage and a very meritorious invention for detecting wireless signals at a time when neither he nor any other scientist understood or appreciated that the same instrumentality would generate wireless waves, must the patent be held within the strict limits of its physical disclosures, the diagrams and the words, or may it go to the point of taking in any result which was obtainable by using precisely that same device with other well known circuits? Now, there is the whole case.

Mr. Darby, Jr.: How about the time?

The Court: Anything that is within reason.

(Briefs to be submitted June 3, 1919.)

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UNITED STATES DISTRICT COURT, SOUTHERN DISTRICT OF  
NEW YORK

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

against

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY,  
Defendant

MEMORANDUM OF MAYER, D. J., HOLDING "AMPLIFIERS"  
WITHIN ORIGINAL DECREE—Filed July 11, 1917

This is the return of an order to show cause why the decree and injunction heretofore made and issued do not cover and include certain devices which defendant makes and sells and why the reports already filed should not be extended to include such devices.

The devices in question are called "amplifiers" and "oscillations."

In the first place, this procedure is correct. It has frequently been followed in this Court and, as I understand, approved by the Circuit Court of Appeals.

The opinions of the Circuit Court of Appeals and of this Court on the main controversy so fully discussed the essential features of the patent and the infringing device that it must be assumed that the litigants are, by this time, fully informed of the views of the two courts. As in the original case, there is again the use of "audion" language which is more or less meaningless from the standpoint of the patent law and certainly does not add to a clear understanding of what has now become reasonably simple, even in an abstruse art.

1. An amplifier consists really of two or more detectors in tandem with a telephone transformer interposed between each element of the series. The primary element of such an amplifier may be either an audion or any other form of detector. In some of the amplifier sets sold by defendant, [6d, 2601] ant, the primary element is a part of the outfit. In other instances, the primary element is not part of the outfit. (See Exhibit E, J. 2.)

I fully agree with Waterman on his facts and explanation as to the "amplifier." In other words, an "amplifier" is part of a detector. In any event, the case falls under the familiar rule of *Robert v. Roer*, 91 U. S. 159, 457, many times since reiterated and followed. I have no doubt whatever that the motion in this regard must be granted.

2. I am not clearly convinced that the Flending valve can perform the functions of an "oscillion" so as to oscillate and generate radio waves. On this branch it will be necessary to give demonstrations or oral testimony, or both, and witnesses should be subject to cross examination. This is really equivalent to a trial. My view is that where the court on an application of this kind is not clearly convinced that the motion should not be granted, then the proceeding should be by bill and answer because the inquiry necessarily develops into a trial and, therefore, the issue should be clearly joined. There is usually little saving of time or labor in short cuts.

The motion, therefore, as to "oscillions" is denied.  
 Submit order on two days' notice.  
 July 11, 1917.

Julius M. Mayer, District Judge

UNITED STATES DISTRICT COURT, SOUTHERN DISTRICT OF  
NEW YORK

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

against

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY,  
Defendant.

OPINION OF MAYER, D. J., HOLDING "OSCILLATIONS" INFRINGE-  
MENTS. Filed July 7, 1919.

J. Edgar Bull and L. F. H. Betts, of New York City, for  
Plaintiff.

Samuel E. Darby and Samuel E. Darby, Jr., both of  
New York City, for Defendant.

Final hearing on supplemental bill.

MAYER, District Judge.

The Fleming patent No. 803684, so far as concerned a [46] 2602] detector for radio waves, was fully discussed in *Harman v. De Forest*, 236 Fed. Rep. 942; affirmed 243 Fed. Rep. 560.

The effect of the decision *supra* of this court, as affirmed by the Circuit Court of Appeals, *supra*, was to accord to Fleming's invention a high place in the art.

Eight or nine years after the date of the Fleming patent, the exact dates are unimportant, Armstrong, Hogan, Waterman, Wengert and probably other experts in the radio art, while using these devices as radio wave detectors, independently observed that the detectors possessed the function of oscillating or, in other words, of generating radio waves. This was an extraordinary additional property or function of the so-called incandescent lamp detector of which Fleming had no knowledge.

Claim 1 of the patent in suit read:

"1. The combination of a vacuum vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, and a circuit outside the vessel connecting the two conductors."

While the claim covers broadly the device when used in the radio art, yet when read with the context of the specification, it is plain that Fleming's disclosure was addressed to use of the instrumentality as a detector only.

It is, however, a principle of the patent law—so well settled as not to call for citations of authority—that a patentee is entitled to all of the benefits of his invention whether or not known to or foreseen by him.

Thus, the first inquiry is whether the Fleming valve, as disclosed by the patent, will oscillate when used in circuits and with instrumentalities available as of the Fleming date and of the kind and character which, upon the evidence, it would be assumed would or could have been used as of that date.

The testimony of the experts and numerous demonstrations in the court room (some required by the court by way of extra caution and assurance), proved beyond peradventure that the two element valve possesses inherently the same capacity for generating radio waves as is possessed by defendant's three element device.

The only question in this connection is whether plaintiff, in order to hold this feature of the Fleming invention, may use a battery.

Obviously the Fleming valve cannot oscillate unless a battery is used; but, to use a battery would, of course, not involve invention, once it is determined that the Fleming valve possesses inherently the ability to generate radio waves.

As counsel for plaintiff aptly say, "one might as well ask whether a boiler could be made to generate steam without a fire under it or whether a dynamo could be made to generate electricity without an engine to drive it."

Indeed, on this branch of the case, the question is whether, in order to make the Fleming valve oscillate, anything need be done or added which would amount to invention. As the answer to this inquiry is plainly in the negative, one necessarily returns to the proposition that as Fleming gave the art a new instrumentality and as that instrumentality [fol. 2903] without inventive changes or additions will oscillate as well as detect, he is entitled to this feature although unknown to him.

The next question is: If the two element valve will certainly and reliably oscillate in common and well-known detector circuits of Fleming's day (Marconi or PN circuit), but will not certainly and reliably oscillate in the precise circuit shown in the Fleming patent without a condenser, is Fleming entitled to the benefits of the device as a generator of oscillations?

The valve was made to oscillate without a condenser although the action in this regard is not certain and reliable; but, this latter fact is immaterial.

The main case has really disposed of this point because this court and the Circuit Court of Appeals have held, *inter alia*, that Fleming's contribution was the device *per se*, which could be used in any circuits and with any instrumentalities then known to the art.

Bell Telephone Case, 126 U. S. 1.

Indeed, the case on analysis is much simpler than when first presented.

On preliminary impression there is reluctance to extend the patent to an unexpected characteristic only observed after a considerable lapse of time by the highly skilled men who are students in the art.

Yet, after all, it was Fleming who made this remarkable contribution of a wholly new device which, of itself, and its development has done so much toward the practical advance of this great art.

The case is fully as meritorious as *Western Electric Company vs. La Rue*, 139 U. S. 691, 695, which, as nearly as may be, presented an analogous question.

Under the authority of that case it is clear that where there is a capacity of reversibility with the same instrumentality, the courts will not restrict the claim to one attribute to the exclusion of the reversible attribute; and, for that matter, this case is stronger than the *La Rue* case because Claim I *supra* is broadly for the instrumentality.

It is concluded, therefore, that the so-called oscillation of defendant infringes and that the decree heretofore filed should be extended thereto with costs.

Submit decree accordingly not later than July 11, 1919.

Julius M. Mayer, District Judge.

July 7, 1919.

[fol. 2694] At a stated term of the United States District Court for the Southern District of New York, held in the United States Court Rooms, in the Borough of Manhattan, City and State of New York, on the 9th day of July, 1919.

Present: Hon. Julius M. Mayer, U. S. D. J.

In Equity No. 12-31. On Fleming Patent No. 803,684

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

Vs.

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY,  
Defendant

This cause having come on to be further heard on the supplemental bill of complaint and answer and proofs taken and filed on behalf of both parties herein and counsel for the respective parties having been heard and due consideration having been had, it is, upon motion of Sheffield & Betts, Solicitors for the Plaintiff,

Ordered, adjudged and decreed that in addition to the devices or apparatus heretofore manufactured and sold by the defendant and decreed to be an infringement of claim 1 of the Fleming patent No. 803,684, in suit, the devices or apparatus called by the defendant "oscillions" which have been manufactured and sold by the defendant separately, as well as the devices or apparatus which the defendant has manufactured and sold comprising "oscillions" alone or in combination with other apparatus or instruments are infringements of said claim 1 of the said Fleming patent in suit; and that any bulbs embodying said claim 1 manufactured and sold by the defendant for use in such "oscillions" or combination of "oscillions" and other instruments or apparatus, are also an infringement of said claim 1, of the said Fleming patent in suit; and that the injunction ordered to issue out of and under the seal of this Court by the Interlocutory Decree of October 9, 1916, and said Interlocutory Decree shall cover and include each and all of such devices or pieces of apparatus and that the defendant shall account to the plaintiff for all damages and profits to which the plaintiff may be entitled by reason of such infringing manufacture and sale as provided for in said Decree of October 9, 1916.

And it is further ordered, adjudged and decreed that the plaintiff, Marconi Wireless Telegraph Company of America, do recover of the defendant, DeForest Radio Telephone

[fols. 2605-2606] and Telegraph Company, the costs and taxable disbursements in connection with said supplemental bill of complaint herein and the trial thereunder.

(Sgd.) J. M. Mayer, U. S. District Judge.

It is hereby consented that the above order may be entered without further notice.

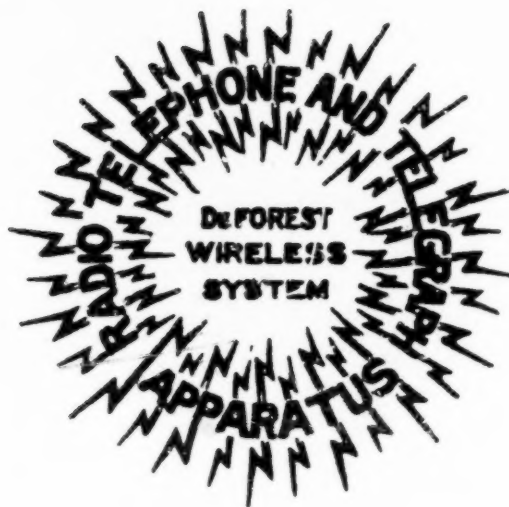
(Sgd.) Sheffield & Betts, Plaintiff's Solicitors; (Sgd.)

Darby & Darby, Defendant's Solicitors.

PLAINTIFF'S EXHIBIT NO. 1

*Bulletin D 16*

# De Forest Radio Telephone Apparatus



Manufactured by

**De Forest Radio Telephone & Telegraph Co.**

NEW YORK CITY

Domestic Sales Office  
101 Park Avenue

Factory and Foreign  
Sales Office  
1391 Sedgwick Avenue

Cable Address: Radiotal, N. Y.

And it is a fact that the Radio Telephone is the only means of communication which is not subject to the ordinary limitations of the ordinary means of communication. It is a fact that the Radio Telephone is the only means of communication which is not subject to the ordinary limitations of the ordinary means of communication. It is a fact that the Radio Telephone is the only means of communication which is not subject to the ordinary limitations of the ordinary means of communication.

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The Radio Telephone is the only means of communication which is not subject to the ordinary limitations of the ordinary means of communication. It is a fact that the Radio Telephone is the only means of communication which is not subject to the ordinary limitations of the ordinary means of communication.

## SOME FACTS ABOUT THE DE FOREST RADIO TELEPHONE AND TELEGRAPH

Compared with the ordinary wireless telegraph, the Radio Telephone can transmit from five or ten times as many words per minute.

As regards its ability to work through adverse interference, static disturbances, etc., the Radio Telephone is actually superior to the Wireless Telegraph. The British Admiralty Tests demonstrated this particularly. Such a percentage of accuracy, for example, as that of only two errors out of a list of 154 numbers (some of five and six figures) as a distance of 50 miles, through severe interference, would have been impossible by means of the spark telegraph.

To replace flag-signalling at sea the Radio Telephone, calling off merely the numbers of the code signals used, has clearly demonstrated its great merit, and this for distances ten times those possible by visual signalling, through fog, smoke, or foul weather, by night as well as day, and with a hundred fold greater speed.

The apparatus is thoroughly reliable. When once properly installed and adjusted, it is simply necessary to turn on the power and throw the transfer switch to one position for talking and to the other for listening.

The transmission of speech is perfect. It is at least as clear and distinct as that over a wire telephone line if not more so.

The experiments conducted at the naval station at Arlington (Washington, D. C.), whereby speech was transmitted to Paris, San Francisco and Honolulu, were carried out on this same system, under license of our patents. This speaks volumes for the range and clearness of speech.

The apparatus is compact and comparatively inexpensive, both from the standpoint of initial and operating costs.

Where electric power is available, the Radio Telephone Set is operated from it by means of a motor generator furnished. The consumption of power is low and entirely within the capacity of any standard electric lighting plant.

Where no electric power can be obtained, a small gasoline engine is furnished, connected to a generator either directly or by belt.

## APPLICATIONS

For yachts and house boats. The Radio Telephone enables the captain or owner to talk to the home, club house or to other craft, saving time and obtaining an instant reply.

For all classes of commercial ships, barges, tugs and lighters. The captain can be in touch with the office and passing ships. No special operator is needed.

For intercommunication between islands and with the mainland, e.g., along the Carolina and Florida Coasts, in Delaware and Chesapeake Bay, the Thousand Islands, etc., the apparatus is now available.

For Revenue Service, coast and inland Surveys, Forestry, etc., the Radio Telephone has a large field.

For connecting offices and factories where wire telephone tolls are excessive or service unreliable.

For emergency or regular service by electric transmission companies to insure communication between generating and sub-stations and switching points at all times.

For communicating on railroads between towers and moving trains. This will be of immense service where unnecessary stopping of trains is an item of importance.

## AND A THOUSAND OTHER VALUABLE USES

We particularly desire to introduce the Radio Telephone for river work—on the waters of the Mississippi and tributaries, not only for steam boats where it is convenient or a genuine economy for the captain to talk direct to a landing station or another boat long before his arrival or passing, but between small towns and stations on opposite banks between which there is no telephone cable.

As shown in the accompanying cuts the new type of De Forest Radio Telephone is distinctly different from all other types. In every particular, from principle to detail, it works a great advance.

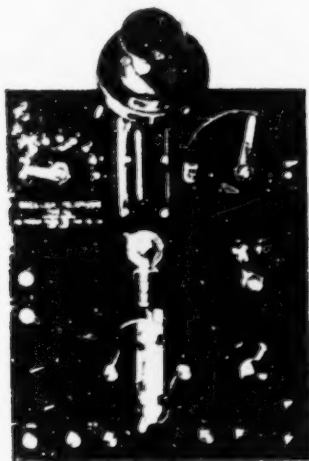
Simplicity of operation and greatest possible freedom from adjustment have been carefully sought, and the present model can be easily manipulated by any intelligent person who follows the very few instructions which are needed.

The arc used in previous types has been completely eliminated. The generator of the high frequency currents is a modification of the now famous De Forest Audion which has been in use for years in the best commercial wireless stations. The Bulletin of the United States Bureau of Standards shows that the Audion is fully 50 per cent more sensitive than any other known form of detector. Its use has doubled the receiving range of wireless equipment during the past few years. It is employed almost to the exclusion of other detectors by the U. S. Navy. The Audion is the one device, above all other factors, which made possible telephony from Coast to Coast on the Bell Telephone System.

It is entirely fitting, therefore, that a form of this famous device should have been developed into a generator of high frequency currents for telephoning without wires, for its constancy and thorough reliability are its distinguishing features and these are absolutely essential in a practical commercial wireless telephone.

### RADIO TELEPHONE

Type OJ.



The cut illustrates the smallest size of transmitter. All the instruments are mounted on a panel of Formica measuring 11 by 18 inches, including the Oscillation Bulb or Tube, potentiometer for close regulation, filament rheostat, impedance coils, loading inductance, telephone transformer and microphone transmitter, fixed condenser and minor accessories. With the set a battery delivering 150 to 300 volts is required. This may be composed of flashlight cells, or a motor generator is supplied where the set is to be used a great deal. The filament operates from a small storage battery. A variable condenser in oil is needed also and is connected to binding posts X' C.

## 83

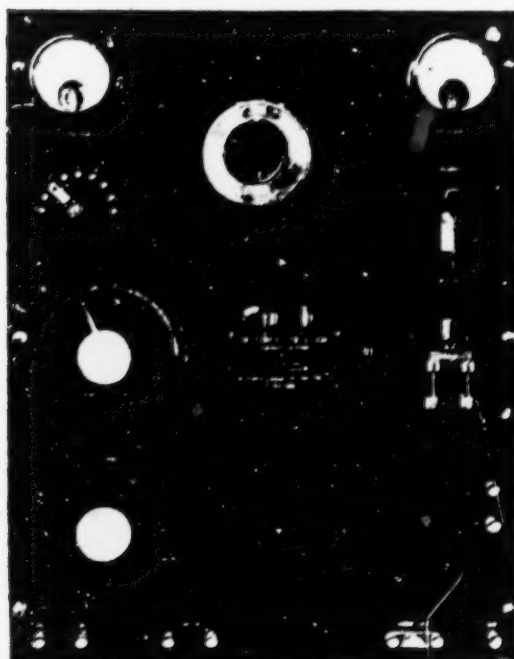
This type of set is particularly adapted for yacht use to communicate to club houses, other ships and residences; also for any purpose where a radius of from one to five miles is sufficient. It may be used as a wireless telegraph transmitter of continuous waves as well, having two or three times the telephone range.

The life of the Oscillon Bulb or Tube when properly used is from 300 to 500 operating hours, equivalent to about a year's service. The set is extremely simple. Once adjusted, no attention is required other than to keep the batteries charged.

This type of radio telephone is furnished as a transmitter only or complete with receiving cabinet and all accessories, as desired. It occupies small space, is simple to install, can be operated by almost any one and is thoroughly reliable and efficient.

### RADIO TELEPHONE

Type OB1.



The cut illustrates the standard radio telephone transmitting panel, measuring 18 by 24 inches. Upon it are mounted all the various parts, all of which, except the transmitter arm, the loading inductance switch, the variable condenser knob, and meters are mounted on the rear. This protects the parts and simplifies the operation.

On the rear are placed the large Oscillon Bulb or Tube, the cooling fan for same, loading coil, telephone transformer and variable condenser, impedance coils and minor accessories.

The two ammeters on the front enable operation at highest efficiency, the one showing the filament current and the other the radiations. By this the operator actually sees himself talk, for the speech causes corresponding deflections of the pointer, showing at all times the condition of the set as a whole.

With the set a motor generator is furnished, designed to operate on any available electric circuit. This furnishes 1200 volts direct current to the Oscillator.

This small type of set has successfully transmitted speech over a distance of 100 miles, in connection with an antenna 300 feet high. With a lower antenna, the range would, of course, be less. The set is arranged so that it may be employed also as a wireless telegraph transmitter of continuous waves. Its range when so used is from two to three times the telephonic range, where the Ultraudion Detector is employed at the distant station.

With this transmitter it is only necessary to connect the antenna and ground to the proper landing posts, connect to the 110 volt direct current source and to the generator and the set is ready to operate. When 110 volts direct current is not available a second generator is provided, directly connected to the motor of the motor generator, to supply same.

For telegraphing where a crystal detector or a plain audion detector is used at the distant station, we supply a chopper or whistling circuit, at additional cost, so that the signals may be received. But it is always recommended, on account of the greatly increased range, to transmit undamped or continuous waves, and equip the distant station with the Ultraudion Detector or Receiving Cabinet.

When this transmitter is adjusted to the desired wave length no further change is required, it being merely necessary to throw the transfer switch from talking to listening or vice versa.

The set is furnished as a complete transmitter, ready to install, or as a complete sending and receiving station, as desired.

## RADIO TELEPHONE

### Type OB2.

This is a larger panel than the Type OB1 Radio Telephone transmitter set is equipped with two Oscillion Bulbs or Tubes, having a cooling fan common to both. The output is approximately 200 watts into an antenna of reasonable size. The motor generator is also of larger capacity, delivering 1500 volts to the High Voltage Tubes.

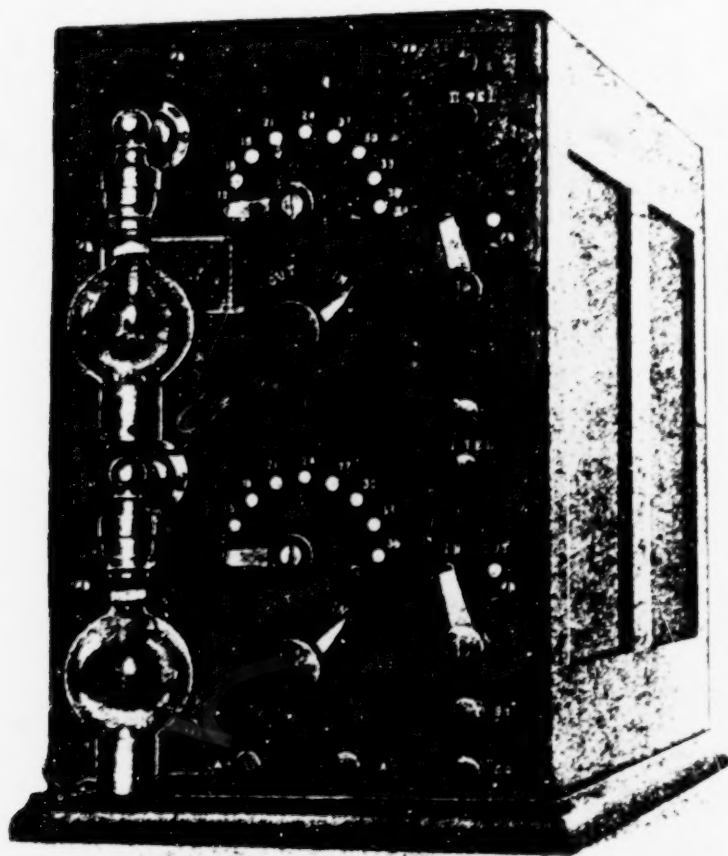
With a suitable antenna the telephone range is from 150 to 200 miles over water and the telegraph range about twice to three times this where the Ultraudion Detector is employed at the distant station.

It may be used either as a telephone or a telegraph, and where a crystal detector is employed at the distant station the transmitter is equipped with a chopper or whistling circuit as in the Type OB1 Transmitter.

With each set of every type complete instructions are furnished.

Prices are quoted on receipt of specifications as to range desired, character of service whether public or private, character of land between stations and kind of power available. If possible a rough sketch should be sent, showing altitudes and general contours to enable us to quote intelligently.

### AUDION AMPLIFIER



**Type P 2, Two-Step Amplifier.**

The De Forest Audion Amplifier in connection with the gives the sound of the received voice, or signals, from 5 to 10 times the type supplied.

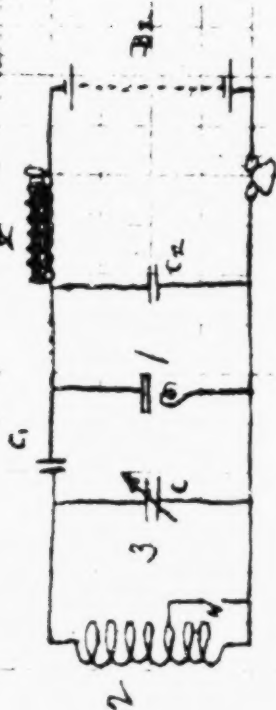
This device increases signals of small intensity with absolute fidelity, and without lag or distortion and is thoroughly reliable. It is the one device, which above all other makes possible telephone communication between the Atlantic and Pacific coasts on the lines of the Bell system. (The A. T. & T. Co. is licensed under the DeForest Audion Patents for wire telephone work.)

Where a greater volume is desired than the Radio Telephone Sets provide, or where the distance between stations is greater than the range of the Set alone, the Amplifier will enable the desired results to be obtained.

This instrument is made in several styles with various degrees of amplification and is more fully described in our special bulletin covering same.

N. B.—This Company owns all the wireless telephone patents of Dr. Lee de Forest and John Stone Stone, covering every method of loose coupling, tuning, microphone-in-earth connection, audion and audion amplifier, etc., etc. We own or are licensed under 185 U. S. Letters patent. Infringers of our telephone system patents will be prosecuted.

## PLAINTIFF'S EXHIBIT No. 2



$C = .001 \mu f. max$

$C_1 = .0004 \mu f.$

$C_2 = .0004 \mu f.$

$L = Core 8" \times 2\frac{1}{4}" \# 22$   
 549 turns Iron wires  
 417 turns #30 d.c.c.

Plugging Two Elements Valve

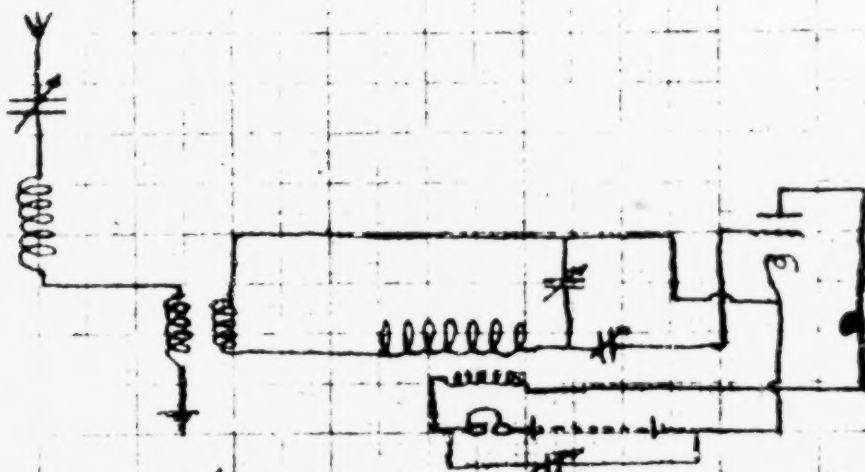
$\lambda = 1500 meters$

0.11 sec.

3037

88

PLAINTIFF'S EXHIBIT No. 3



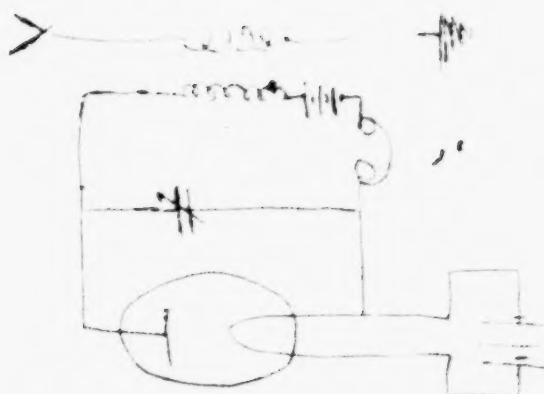
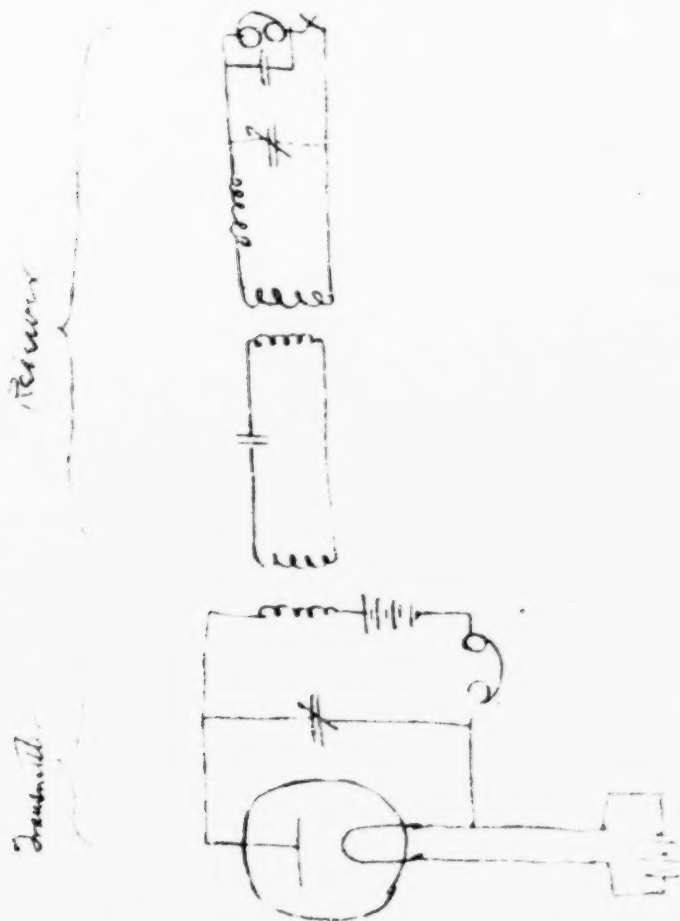
Navy Short Wave Receiver  
Type CM 294C

Extra meter wiring

C.B. Kent '19

*Plaintiff's Exhibit Waterman's Sketch*  
*( May 16 1919 )*

89



90

# PLAINTIFF'S EXHIBIT

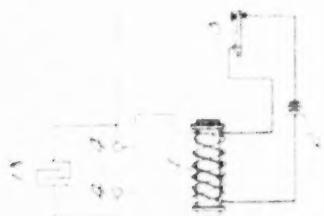
No 706,735

Patented Aug. 12, 1902

R. A. FESSENDEN  
WIRELESS TELEGRAPHY  
Application filed Dec. 18, 1899

(No Model)

3 Sheets—Sheet 1



2

FIG. 1



WITNESSES

*W. H. ...*  
*...*

INVENTOR

*Reginald A. Fessenden*  
*by ...*

ATTY.

No 706,735

Patented Aug 12 1902

R. A. FESSENDEN  
WIRELESS TELEGRAPHY

Application filed Dec. 15 1900

No Model

3 Sheets Sheet 2

FIG 2



FIG 5

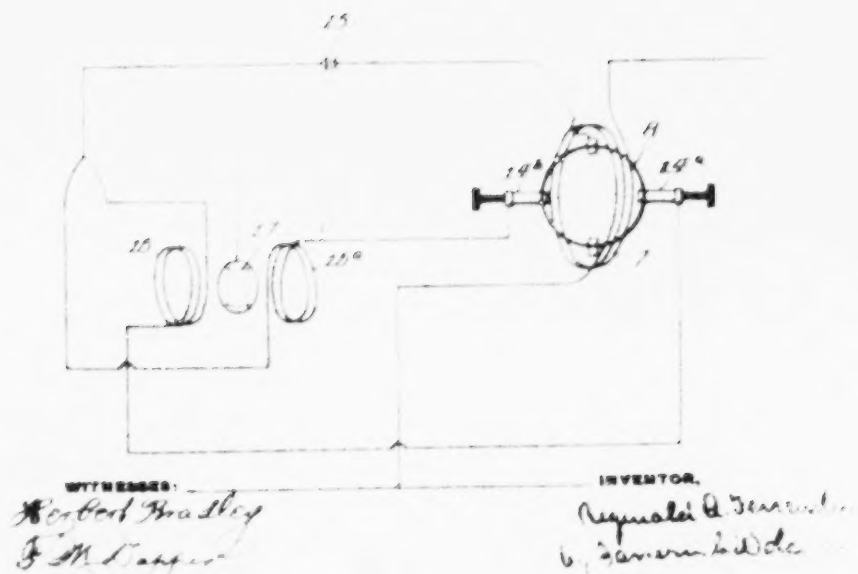


FIG 3

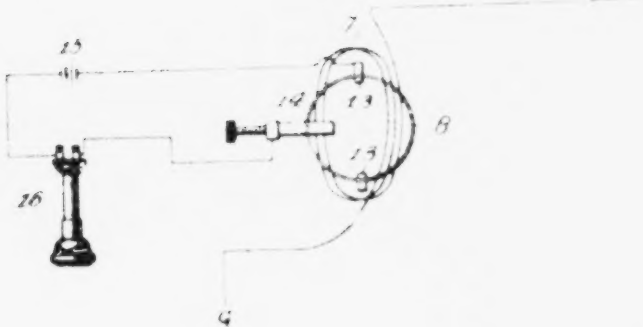
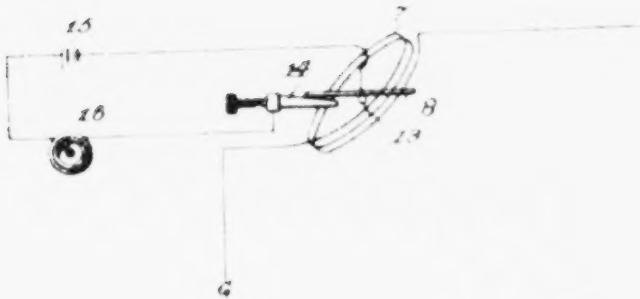


FIG 4.



WITNESSES:

*Robert Bradley*  
*J. M. Rapp*

INVENTOR,

*Reginald A. Fessenden*  
by *Daniel B. Wolcott*  
ATTY.

# UNITED STATES PATENT OFFICE.

REGINALD A. FESSENDEN, OF ALLEGHENY, PENNSYLVANIA

## WIRELESS TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 700,735, dated August 12, 1902.  
Application filed December 15, 1899. Serial No. 740,479. (No model.)

*To all whom it may concern:*

Be it known that I, REGINALD A. FESSENDEN, a citizen of the United States, residing at Allegheny, in the county of Allegheny and State of Pennsylvania, have invented or discovered certain new and useful improvements in Wireless Telegraphy, of which improvements the following is a specification.

The invention described herein relates to certain improvements in the electrical transmission of signals from one station to another without the use of conductors connecting such stations.

In the methods heretofore employed the electromagnetic waves generated at the receiving station produce voltages in the receiving circuit. These voltages passing through a suitable material normally non-conductive render the same conductive, and thereby permit the passage of a current through a circuit in which said material, usually termed a "coherer," is included. After the cessation of the voltages produced by each series of electromagnetic waves generated at the sending station the coherer must be operated on in some way to restore it to normal or non-conductive condition.

The object of the present invention is to provide for the generation by currents produced by electromagnetic waves of currents in a second element or circuit and by the reaction of the current in this second element or circuit on the field formed or produced by the currents in the receiving wire to produce motion which is directly or indirectly observable.

In general terms the invention consists in the generation by electromagnetic waves of a current directly or indirectly in coils at the receiving station, the current in said coils inducing a current in another element or circuit which is arranged in such relation to the coils that the current induced therein reacts with the field produced by the coils, thereby producing motion.

The invention is hereinafter more fully described and claimed.

In the accompanying drawings, forming a part of this specification, Figure 1 is a diagrammatic view showing the arrangements employed at the sending and receiving stations. Figs. 2 and 3 are diagrammatic views

illustrating modifications of the receiving apparatus. Fig. 4 is a side elevation of the apparatus shown in Fig. 3, and Fig. 5 is a further modification of the receiving apparatus.

The apparatus employed at the sending station may be similar to that now in use for the generation of electromagnetic waves and consists of an induction-coil 1, having its primary coil in circuit with a generator 2, said circuit having a make-and-break mechanism 3 included therein. One of the discharging knobs or terminals 4 is connected with the vertical sending-conductor 5, while the other knob or terminal is grounded. I have found that by placing a capacity formed by a body 6 of conducting material having a comparatively large radiating-surface the waves generated at the sending station have a very much higher energy, thereby correspondingly increasing the effect or energy of the current produced in the receiving conductor.

The terms "sending-conductor" and "receiving-conductor" are employed herein as indicating all of the circuits at the sending and receiving stations from top to ground, if grounded, or if not grounded from one extreme end to the other extreme end, including all apparatus in series with the circuits, while the term "radiating portion" indicates all of the sending-conductor from top or extreme end of same to point of junction with the apparatus for effecting the oscillatory charging and discharging thereof, such as sparking terminals, transformer-coils, armature windings, &c. By the term "electromagnetic waves" as used herein is meant waves of a wave-length long in comparison with the wave-length of what are commonly called "heat waves" or "radiant heat." By "grounded conductor" is meant a conductor grounded either directly through a capacity, an inductance, or a resistance, so that the currents in the conductor flow from the conductor to ground, and vice versa, when electromagnetic waves are being generated. The terms "tuned" and "resonant" are used herein as one including the other. By the term "current-operated wave-responsive device" as used herein and by me generally is meant wave-responsive devices having their contacts good contacts and operated by currents produced by electromagnetic

netic waves. They are hence to be distinguished from wave-responsive devices depending for operation upon varying contact resistance.

At the receiving station the receiving conductor is formed by a wire or wires 6, projecting up vertically or at an inclination to a suitable height, which are also grounded. A coil or coils 7 are arranged in the circuit of the receiving conductor 6, and an element or coil of wire 8, forming a closed circuit, is supported with a freedom of movement in such relation to the coil or coils 7 that the current produced by the electromagnetic waves will induce a current in the element 8. The element 8 is supported, preferably, in such manner that a plane at right angles to its axis will form an angle of approximately forty five degrees, (45°) with a plane at right angles to the axis of the coils 7, so that the reaction of the current induced in said element with the field produced by the coils 7 will cause the element 8 to move with reference to the coils 7. This motion of the element may be observable by means of a mirror 9, attached thereto, reflecting a beam of light on a scale, or said element may form a part of the circuit of a recording siphon, &c.

As shown in Fig. 2, the coils 7 may be connected to the secondary coil 11 of a transformer whose primary coil 12 is connected in series with the receiving wire.

A desirable means for transforming the electromagnetic waves into recordable motion is shown in Figs. 3 and 4. The element 8 is balanced on supporting rods or knife-edges 13, one of which is formed of a good electrical conductor, as silver, the element 8 being preferably formed by a silver ring. A carbon block 14 is so arranged that a portion of the ring between the supporting rods will normally rest lightly thereon. This microphonic contact, the conducting pivotal support, and the portion of the ring between them form parts of an electric circuit, which also includes a generator 15 and a recording instrument 16 as a telegraphic sponder or the receiver of a telephone. When a current is generated, as above described, in the coil 7, the element or ring 8 will be caused to press on the carbon block, thereby increasing its conductivity. When using a telephone receiver as a recording instrument, the generator 15 is preferably of a character capable of producing an alternating current, as such current causes a constant vibration of the diaphragm, the vibrations increasing in intensity with an increased flow of current in the circuit. This increase in intensity of action with increased flow of current is characteristic of this form of receiver and also of the form shown in Fig. 1. In this it is sharply differentiated from such devices as the coherer, which either give a strong indication or do not give any. This characteristic is advantageous in that if the signal sent—any dot—be too weak to give an action of the

full intensity it may still in most cases be read and not missed entirely, which is of value in sending code-messages.

In the construction shown in Fig. 5 the circuit of the generator is divided, one branch including a coil 16 and connected to a microphonic contact 14, while the other branch of the circuit includes a reversely-wound coil 16' and is connected to a microphonic contact 14'. These contacts are arranged on opposite sides of the ring 8 and are so adjusted that the ring will normally rest equal on both blocks, so that an equal current will flow through both of the coils 16 16', thereby maintaining a magnetic bar 17, suspended between the coils in equilibrium with relation to the coils. Adjustable resistances may be placed in the circuits of the coils, thereby avoiding the necessity of delicate adjustments of the carbon blocks. When the coils and the ring or element 8 are energized, the pressure of the latter on one contact is increased and that on the other decreased, thereby correspondingly changing the resistances in the two branches. The increased flow of current through one coil and decreased flow through the other coil, due to the change in resistances, will produce a greater movement of the magnetic bar 17 than if only a single coil were used. The movement of the bar 17 can be rendered observable in many ways known in the electric signaling art—as, for example, by securing a mirror thereon.

As shown in Fig. 1, a condenser 19 may be connected in shunt with the field coil or coils 7 for the purpose of obtaining as large a current as possible in the field-coil 7, as this increase in current will give a greater torque to the ring 8. When no condenser is employed, this large current must flow in the vertical wire, and there would be great loss of energy on account of the resistance of wire 6, and, further, without the condenser a large amount of energy will be required to give the statical charge to the receiving-conductor. Hence on account of the small energy furnished by the wave a large current cannot be obtained in field coil or coils 7 without the condenser. By employing a condenser of the proper size current in wire 6 may be made to have a value equal to the difference between the current in the field coil or coils and the current in the condenser. Either of these currents may therefore be large and either or both may be used to produce motion, while the current in wire 6 may be kept so small that there is practically no loss of energy on account of its resistance or of the statical charging of the receiver, and all the energy may be used in producing motion. Without the condenser the current in the field coil or coils 7 will be practically a quarter phase behind the voltage on account of the self inductive lag in the field-coil. If the condenser were substituted for the field coil, there would be a current in it nearly a quarter-phase in advance of the voltage due to the capacity lead. When both the

field coil and the condenser are introduced one in shunt with the other, there will be a current in the field coil or coils lagging ninety degrees ( $90^\circ$ ) and in the condenser a current leading ninety degrees, ( $90^\circ$ ). The sum of two currents one hundred and eighty degrees apart in phase is equal to the difference between their values. Hence if there is a current in the field coil or coils of one ampere and in the condenser a current of nine-tenths ( $\frac{9}{10}$ ) of an ampere the current in the receiving wire will be one-tenth ( $\frac{1}{10}$ ) of an ampere.

By the employment of a condenser in shunt with the coil or coils the current in the receiving wire is reduced without reducing the current in the coil or coils, so that the resistance drop, which is at times sufficiently great to affect the operation of the system, is eliminated or so reduced as not to have any material effect.

It is preferred to place a shunt circuit containing a condenser across the terminals of the induction coil at the sending station for the purpose of maintaining sustained radiation. This shunt circuit must be tuned to the receiving conductor; otherwise the oscillations produced by it will have no action upon the wave responsive device at the receiving station. This shunt circuit by virtue of its capacity stores up an additional amount of energy, and when a spark passes across the gap, since the sending conductor can radiate energy at a given rate, it must continue to radiate for a longer time in order to dissipate this additional stored-up energy.

I am aware that apparatus consisting of a fixed primary and a movable secondary circuit has been used for detecting oscillatory currents. This apparatus was a modified form of an earlier alternating voltmeter, a silver disk or thick-rimmed annulus being substituted for the wire coil used in the voltmeter and delicately suspended so as to have a long period of swing. This apparatus was used not for the purpose of detecting electromagnetic waves emitted and received by unclosed circuits, but for detecting the magnetic inductive effects which one closed circuit (having rapidly oscillating currents produced in it by a transformer, Hertz oscillator, or other suitable means) produced on another closed circuit. The effects to be obtained by such an apparatus were therefore different in kind from those sought in wireless telegraphy and the method of producing them were different from that described herein. This Northrup apparatus was used to detect magnetic induction effects to a distance of approximately one hundred yards. Although distances somewhat longer could doubtless have been attained with such apparatus, the method employed by Northrup is not available for commercial wireless signaling, as magnetic induction effects fall off as the cube of the distance, and approximately ten thousands of millions times the energy would be

required to obtain effects with the Northrup apparatus at a distance of one hundred miles.

The construction of Northrup's receiving instrument is not suitable for the purposes of wireless telegraphy, as the movable member consists of a disk or thick-rimmed annulus, whereas the movable member of the receiving mechanism for wireless telegraphy should be a ring formed of thin wire (indicated at 8 in the drawings) having a ratio of internal and external diameters equal or approximately equal to unity. If a disk or thick-rimmed annulus should be used as the movable member of the receiving mechanism for wireless telegraphy, the efficiency of such mechanism would be so greatly reduced as to render it inoperative, for the reason that the currents induced in the disk or thick-rimmed annulus tend to get as near as possible to the center of such parts, and thereby weaken the reactive effect between the fixed and movable parts as to exert small torque, and, further, as the disk and thick-rimmed annulus have low self-induction the currents induced in them tend to get out of phase with the currents in the fixed coil or coils, and hence the torque is weakened. Moreover, the period of oscillation of a disk or thick-rimmed annulus for a given restoring force is so long that extremely powerful restoring forces must be used to enable a mechanism having such a movable member to record signals at commercially practical speeds, and since the force varies as the square of the speed deflecting forces many thousands of times greater must be employed than is required in the receiving mechanism described herein. In other words, the thin light ring will work with but a fraction of the energy required to operate a disk or thick-rimmed annulus. By the employment of a thin ring of good conducting material and a fixed coil of few turns, as shown in the drawings, the electrical forces between fixed and movable members of the receiving mechanism are rendered more efficient, and hence the force necessary for commercially practical signaling is greatly lessened.

The inapplicability of the Northrup apparatus is further shown by the fact that the coils of the fixed member of his apparatus consist of a large number of turns of wire, so that the resistance in such coils is high, whereas a commercially-practicable instrument for wireless telegraphy should have its fixed coil or coils formed by a few turns of wire, and consequently of low resistance. By the employment in the receiving instrument of a fixed coil or coils of few turns and a movable member formed by a thin light ring of highly conducting wire high resonance effects combined with a rapid natural period of the moving part and a maximum efficiency are attained and the advantageous use of transformers, as in Fig. 2, is rendered possible.

It is characteristic of the method shown that the receiving mechanisms are actuated by currents produced by electromagnetic waves and not by voltages, as in the case of the coherer. Hence when the receiving mechanisms described herein are used in connection with a secondary circuit said circuit is controlled by the currents generated by electromagnetic waves and not by voltages. It is also characteristic that when a secondary circuit is used in connection with the type of wave-responsive device shown in Figs. 3, 4, and 5 a portion of the secondary circuit is traversed and controlled by currents produced by electromagnetic waves. It is further characteristic of my improved system that the indications produced by the receiving mechanism herein described are dependent upon the total amount of energy emitted to form the signal and are not, as in the case of the coherer, dependent upon the maximum of the voltage.

I claim herein as my invention—

1. As an improvement in the art of transmitting signals electrically by electromagnetic waves the method herein described, which consists in the generation of electromagnetic waves at one station and transforming the energy of the currents generated by such waves at the receiving station into the energy of motion, that is without the necessary interposition of a secondary or auxiliary generator for the production of such motion, substantially as set forth.

2. As an improvement in the art of transmitting signals between stations by electromagnetic waves, the method herein described which consists in causing the radiation of electromagnetic waves from a grounded conductor, generating voltages by such waves in a conductor at the receiving station and transforming the energy of each of said voltages into the energy of motion, substantially as set forth.

3. As an improvement in the art of transmitting signals electrically between stations by electromagnetic waves, the method herein described which consists in producing an electromagnetic field in a receiving mechanism consisting of relatively fixed and movable members arranged in operative relation to each other by the generation of electromagnetic waves at the sending station, thereby causing a movement of one of the parts of the receiving mechanism, substantially as set forth.

4. As an improvement in the art of transmitting signals electrically between stations by electromagnetic waves, the method herein described which consists in the generation of a current or currents in a portion of a receiving mechanism consisting of relatively fixed and movable members by the generation of electromagnetic waves at the sending station and then producing a current or currents in the other portion of the receiving mechanism by the current or currents generated by the

electromagnetic waves, whereby one part of the receiving mechanism is caused to move relative to the other part, substantially as set forth.

5. As an improvement in the art of transmitting electrical energy by electromagnetic waves the method herein described, which consists in maintaining a secondary circuit in an energized condition and controlling the energy of said circuit by current effects produced by electromagnetic waves flowing through a current-operated wave responsive device forming a portion of the secondary circuit.

6. As an improvement in the art of transmitting electrical energy by electromagnetic waves the method herein described, which consists in prolonging the oscillations of an energy-radiating conductor by energy from a source external to the radiating conductor and tuned to the period of the radiating conductor, substantially as set forth.

7. As an improvement in the art of transmitting electrical energy by electromagnetic waves the method herein described, which consists in the generation of electromagnetic waves at one station and transforming the energy of the currents generated by such waves at the receiving station into the energy of motion, varying the motion thus produced by varying the amount of energy delivered at the receiving station without the necessary interposition of a secondary or auxiliary generator for the purpose of such motion, substantially as set forth.

8. As an improvement in the art of signaling by electromagnetic waves the method herein described, which consists in generating electromagnetic waves in a grounded conductor at the sending station, receiving such waves at the receiving station and transforming the energy of electromagnetic waves so received into the energy of motion by means of a receiving instrument having a low resistance, substantially as set forth.

9. As an improvement in the art of transmitting electrical energy, the method herein described, which consists in varying the conductivity of a secondary circuit at the receiving station by motion produced by currents generated by electromagnetic waves, substantially as set forth.

10. As an improvement in the art of transmitting electrical energy, the method herein described, which consists in the generation of electromagnetic waves at one station transforming the energy of the currents generated by such waves at the receiving station into energy of motion, varying the currents in two or more local circuits by such energy of motion and transforming the energy of such currents into the energy of motion, substantially as set forth.

11. As an improvement in the art of transmitting electrical energy, the method hereby described, which consists in generating electromagnetic waves at one station, transforming the energy of currents generated by such

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waves into the energy of motion, varying the  
current in two or more local or secondary cir-  
cuits by such energy of motion, transforming  
the energy of the varied currents into the en-  
5 ergy of motion and causing the energies of  
motion so produced to operate in the same di-  
rection, substantially as set forth.

In testimony whereof I have hereunto set  
my hand.

REGINALD A. FESSENDEN.

Witnesses:

DARWIN S. WOLCOTT,  
F. E. GAITHER.

PLAINTIFF'S EXHIBIT

No. 711,131

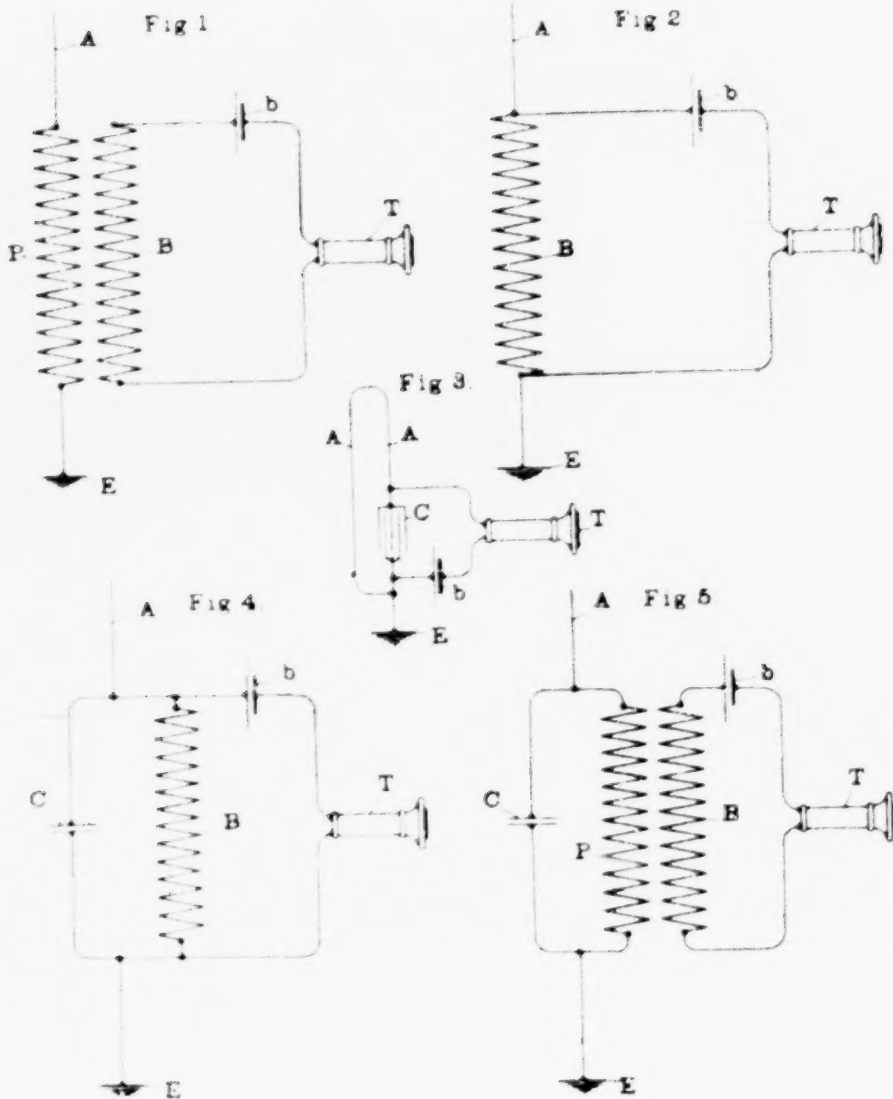
Patented Oct. 14, 1902.

H. SHOEMAKER.

ART OF TRANSMITTING INTELLIGENCE

Application filed Aug. 9, 1900.

(No Model)



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# UNITED STATES PATENT OFFICE.

HARRY SHOEMAKER, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO  
CONSOLIDATED WIRELESS TELEGRAPH AND TELEPHONE COMPANY  
AND MARIE V. GEHRING, OF PHILADELPHIA, PENNSYLVANIA.

## ART OF TRANSMITTING INTELLIGENCE.

SPECIFICATION forming part of Letters Patent No. 711,131, dated October 14, 1902.

Application filed August 9, 1902. Serial No. 119,030. (No model.)

*I wish whom it may concern:*

Be it known that I, HARRY SHOEMAKER, a citizen of the United States, residing at Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented a new and useful Art of Transmitting Intelligence, of which the following is a specification.

My invention relates to an improvement in the art of signaling electrically, more particularly by means of electroradiant energy which is impressed upon the natural media and which causes manifestations at the receiving stations.

My invention comprises a method of receiving signals represented by electroradiant energy by causing such energy to change the resistance of a material in virtue of a magnetic field caused by such energy. Of such materials many are well known in the electrical arts, though bismuth is a good example of the same.

My invention consists of a method of rendering intelligible transmitted electroradiant energy by causing such energy at the receiving station to cause a varying magnetic field in which is placed a material having the property of changing its resistance under the influence of magnetism and producing a signal or recording a message by the changes of resistance of such material.

My invention consists, further, of a method of rendering intelligible transmitted electroradiant energy by causing such energy in the receiving circuits to vary, either directly or indirectly, the resistance of a material which is not in the nature of an imperfect electrical contact, but rather in the nature of a continuous conductor of relatively low resistance or great conductivity as compared with the imperfect electrical contacts known in the art of wireless signaling.

By the use of bismuth or other materials which change their resistance when in a magnetic field I am enabled to construct a receiving device for wireless signaling systems in which the received electroradiant energy causes, directly or indirectly, a change in the resistance of such material, and the change of such resistance is caused to control a local

circuit to produce a signal or record a message. The use of such material is distinctly different from the use of imperfect contacts now well known in the art as coherers and the like, which in general manifest great and sudden changes in resistance and are more or less uncertain in their action.

By employing bismuth or other similar material and subjecting it to the varying magnetic field due to received electroradiant energy there is attained a smooth variation in the resistance of a circuit, which renders the receiver certain in its operation, in marked contrast with the operation of the imperfect electrical contacts heretofore employed in wireless signaling systems.

Besides bismuth it is to be understood other materials may be used which have the same property—namely, that of changing resistance when in a magnetic field. I have found that iron, and even copper, behaves similarly to the bismuth when placed in a magnetic field.

Reference is to be had to the accompanying drawings, in which—

Figure 1 is a diagrammatic view of the receiving-circuits of a wireless signaling system in which a bismuth conductor is placed in the field generated by received energy within a winding in series with the aerial conductor. Fig. 2 is a diagrammatic view in which the bismuth or like material is connected in series with the aerial conductor. Fig. 3 is a diagrammatic view in which a loop of bismuth or like material is used for the aerial conductor and comprises in these two aerial conductors bismuth or other material which are connected at their tops. Fig. 4 is a modified arrangement of the circuits of a receiving device in which by proper proportions of the electrical constants of the circuit the magnetic field produced by the arriving energy is very great compared with the amount of such energy. Fig. 5 is similar to Fig. 4, except that the bismuth or other material is placed in the field generated by a winding through which an abnormal amount of current flows under the influence of a certain amount of received energy.

In Fig. 1, A represents the usual aerial conductor, in series with which is connected the winding P, which connects at its lower terminal with earth plate E. The received radiant energy causes oscillations in the aerial conductor and through the winding P to manifest a magnetic field. Within this field is placed a length of bismuth, preferably in the form of wire B, forming a part of the circuit including the telephone receiver T and the source of energy  $\mathcal{E}$ . The bismuth is normally has a certain resistance, and there is accordingly a certain current flowing through the telephone receiver T, producing no sound. Upon the reception of electrical energy, however, the resistance of B varies, due to the magnetic field generated by the winding P, and there results a fluctuation of current through the receiver T, causing a sound to be produced in accordance with the received energy. In this manner the code characters or other signal characters may be read by the ear.

In Fig. 2, A is the usual aerial conductor, in series with which there is connected a bismuth winding B, which connects at its lower terminal with the earth plate E. The received radiant energy causes oscillations through said conductor A, producing a magnetic field. This magnetic field generated by the winding A causes in the conductor B a change of resistance, which is noted by means of the telephone receiver T and the source of energy  $\mathcal{E}$ , as in the case of Fig. 1.

In Fig. 3, A A represent two aerial conductors, of bismuth or similar material, which conductors are joined at their upper ends. The left hand conductor A connects directly to earth plate E, while the right hand conductor connects to earth plate E through condenser C. The condenser C is so large as to be perfectly transparent to the oscillations received in the right hand conductor A, and in effect, therefore, the right hand conductor A is connected directly to earth. In shunt to the condenser C, or, what is the same thing, in series with the two conductors A A are connected the telephone receiver T and the source of energy  $\mathcal{E}$ . In this case the conductors upon the reception of radiant energy are surrounded by a magnetic field, and such field in turn causes a variation of resistance of such conductors A A. There results, therefore, a variation in the resistance of the circuit embracing source of energy  $\mathcal{E}$ , telephone receiver T, right hand conductor A, and left hand conductor A. From such change of resistance there results a variation in the flow of current through the telephone receiver T, producing a signal, as previously described.

In Fig. 4, A is the usual aerial conductor, between which and the earth plate E are connected the condenser C and inductance winding B in parallel relation to each other. The condenser C and this inductance winding B are so related to each other as to their magnitudes that they form what is known as an "antiresonant" or "closed resonant" circuit

for the frequency of oscillations which are received upon the aerial conductor A. When the radiant energy received upon the said conductor A is of a particular frequency, there is set up in the local circuit, embracing the condenser C and the inductance B in series with each other, a current many times greater than that appearing in the aerial conductor itself. This inductance B is composed of bismuth wire. The excessive current flowing through it, due to the relations above stated, causes an abnormally powerful magnetic field to be produced in the vicinity of said winding, resulting in a correspondingly great variation in resistance of the bismuth wire forming the winding of such inductance. The variation in resistance of such bismuth inductance B is recorded then by the telephone receiver T, with the aid of the source of energy  $\mathcal{E}$ , as described in the previous cases.

In Fig. 5, A is the aerial conductor, between which and the earth plate E are connected in parallel with each other the condenser C and the primary winding P. The relations of this condenser C and the winding P are the same as described in connection with Fig. 4 for the condenser C and the inductance B. As described in connection with Fig. 4, the winding P will produce an abnormally strong magnetic field due to the antiresonant effect, and within this field is located a bismuth conductor B, as in the case shown in Fig. 1, and the variation of resistance of such conductor B is recorded by the telephone receiver T with the aid of the source of energy  $\mathcal{E}$ .

I do not wish to be limited to the present arrangement of circuits as herein described by me, for it is apparent that this system may be applied in many other relations by those skilled in the art. It is broadly new to me to generate a magnetic field by the received electroradiant energy and to cause such field to vary the resistance of certain materials and cause such variation of resistance to control a local circuit to produce a signal or record a message.

It is of course to be understood that in place of telephone receivers sensitive relays may be employed to control local circuits. Furthermore, the telephone receivers may be omitted and the primary of a transformer substituted therefor, and in the secondary circuit of such transformer may be placed telephone receivers or other devices, such as relays and the like. By this arrangement upon a change of resistance in the bismuth or like material there is a large change in the strength of the current in the primary of the transformer, because a large source of energy is used, resulting in a great change in the ampere-turns of the primary of the transformer, and consequently a great change in the potential of the secondary circuit.

In the arrangement shown in the drawings the telephone receivers are to be of low resistance, so that normally there may be a relatively large current flowing through the

telephone-receiver. In virtue of this slight change in resistance of the material there will be considerable change in the current strength, and therefore considerable change in the ampere-turns in the telephone-receiver.

The bismuth or other material as used in my system may be in the form of a wire. The cross-section of the conductor or wire is such as to permit the use of a considerable current in the circuit of the wave-responsive device, which is, in fact, the wire. Heretofore in wireless signaling systems but very slight amounts of current had been used in the wave-responsive device. In the case of coherers and the like the current has been extremely small, and in the case of other systems employing a metallic conductor as a wave-responsive device the current employed has been extremely small. In my system, however, I am enabled for the first time in the art to employ currents of relatively great magnitude through the wave-responsive device. This is an advantage which is appreciated in view of the considerations named above. In other words, if the telephone-receiver I were of high resistance as compared with the bismuth or like material the slight fluctuation in the resistance of such material would cause but slight effect in the receiver. The bismuth or other material being of relatively low resistance, the telephone-receiver should also be of relatively low resistance.

What I claim is—

1. The method of rendering intelligible transmitted electradiant energy representing a signal, which consists in varying the resistance of a material by a magnetic field which varies with the transmitted energy, and recording the variations of resistance of said material.

2. The method of rendering intelligible transmitted electradiant energy representing a signal, which consists in changing the resistance of a material by a magnetic field due to the transmitted energy, and recording the changes of resistance of said material.

3. The method of rendering intelligible transmitted electradiant energy representing a signal, which consists in changing the resistance of a material by a magnetic force due to the transmitted energy, and producing a signal by the change of resistance of said material.

4. The method of rendering intelligible transmitted electradiant energy representing messages, which consists in transforming the received electradiant energy into the energy of electric currents, generating a magnetic field by said currents, subjecting a material to said field to vary its resistance, and recording the resistance changes of said material.

5. The method of rendering intelligible transmitted electradiant energy representing messages, which consists in transforming the received electradiant energy into the energy of electric currents, producing a mag-

netic force by said currents, changing the resistance of a material by said magnetic force, and recording the resistance changes of said material.

6. The method of rendering intelligible transmitted electradiant energy representing a message, which consists in generating a magnetic field by the received energy, changing the resistance of a material by said magnetic field, and recording the resistance changes of said material by varying the current strength in a circuit of a translating device.

7. The method of transmitting intelligence, which consists in impressing upon the natural media electradiant energy representing a message, converting the received energy into the energy of electric currents at the receiver, increasing the current component of said energy of electric currents in a closed resonant circuit, generating a magnetic force by the increased current component, varying the resistance of a material by and in accordance with said magnetic force, and recording the resistance changes of said material.

8. The method of rendering intelligible electradiant energy transmitted through the natural media and representing a signal, which consists in producing a magnetic field by the received energy, changing the resistance of a material by the influence of said magnetic field, and producing a signal by the change of resistance of said material.

9. The method of rendering intelligible electradiant energy transmitted through the natural media and representing a signal, which consists in producing a magnetic field by the received energy, changing the resistance of a mass of bismuth by the influence of said magnetic field, and producing a signal by the change of resistance of said mass of bismuth.

10. The method of rendering intelligible transmitted electradiant energy representing a signal, which consists in varying the resistance of a mass of bismuth by a magnetic field which varies with the transmitted energy, and recording the variations of resistance of said mass of bismuth.

11. The method of rendering intelligible transmitted electradiant energy representing a signal, which consists in generating a magnetic field by the received energy, varying the resistance of a material by said varying magnetic field, and recording the resistance changes of said material.

12. The method of rendering intelligible transmitted electradiant energy representing a signal, which consists in generating a magnetic force by the received energy, varying the resistance of a mass of bismuth by said magnetic force, and recording the resistance changes of said mass of bismuth.

HARRY SHOEMAKER

Witnesses

C. S. EYER,

ALICE P. BURROUGHS

PLAINTIFFS' EXHIBIT

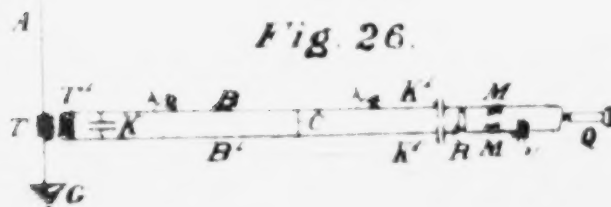
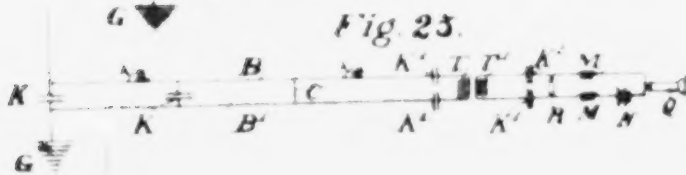
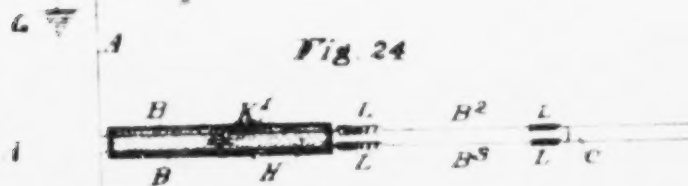
No. 730,246

PATENTED JUNE 9, 1903.

L. DE FOREST  
SPACE TELEGRAPHY  
APPLICATION FILED MAR 8 1903

SHEET-SEAST 1

NO NOTES



WITNESSES  
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*H. L. Bell*

IN WITNESS WHEREOF  
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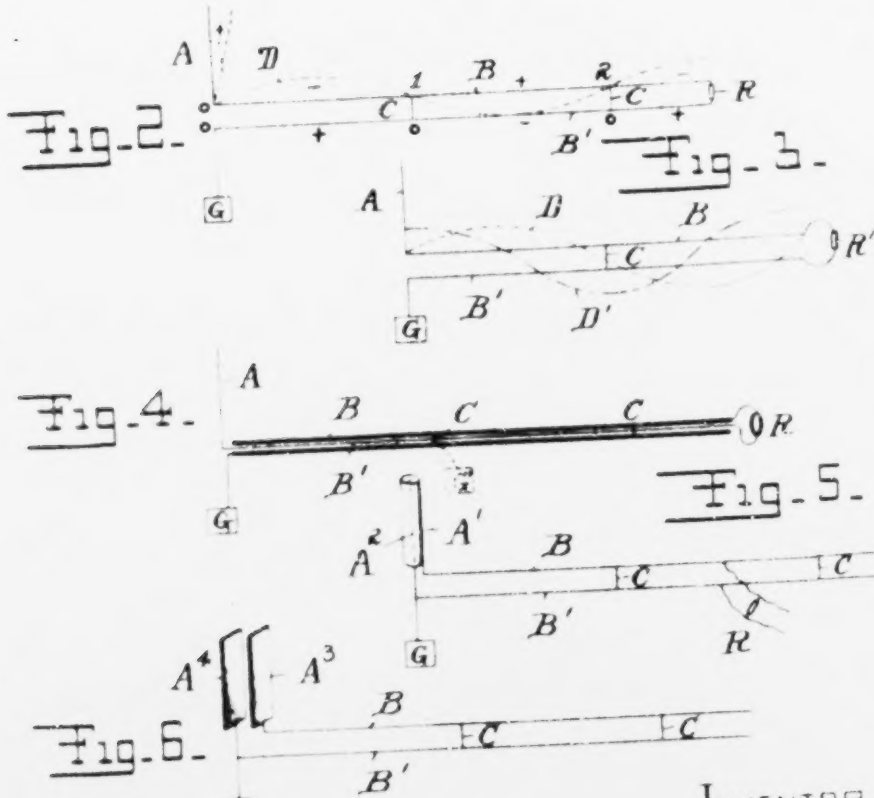
No. 730,246

PATENTED JUNE 9, 1903

L. DE FOREST.  
SPACE TELEGRAPHY.  
APPLICATION FILED MAR 8 1903

2 SHEETS SHEET 1

NO MODEL



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No. 730,246.

PATENTED JUNE 9, 1903

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SPACE TELEGRAPHY

APPLICATION FILED MAR 6 1902

NO MODEL

6 SHEETS-SHEET 1



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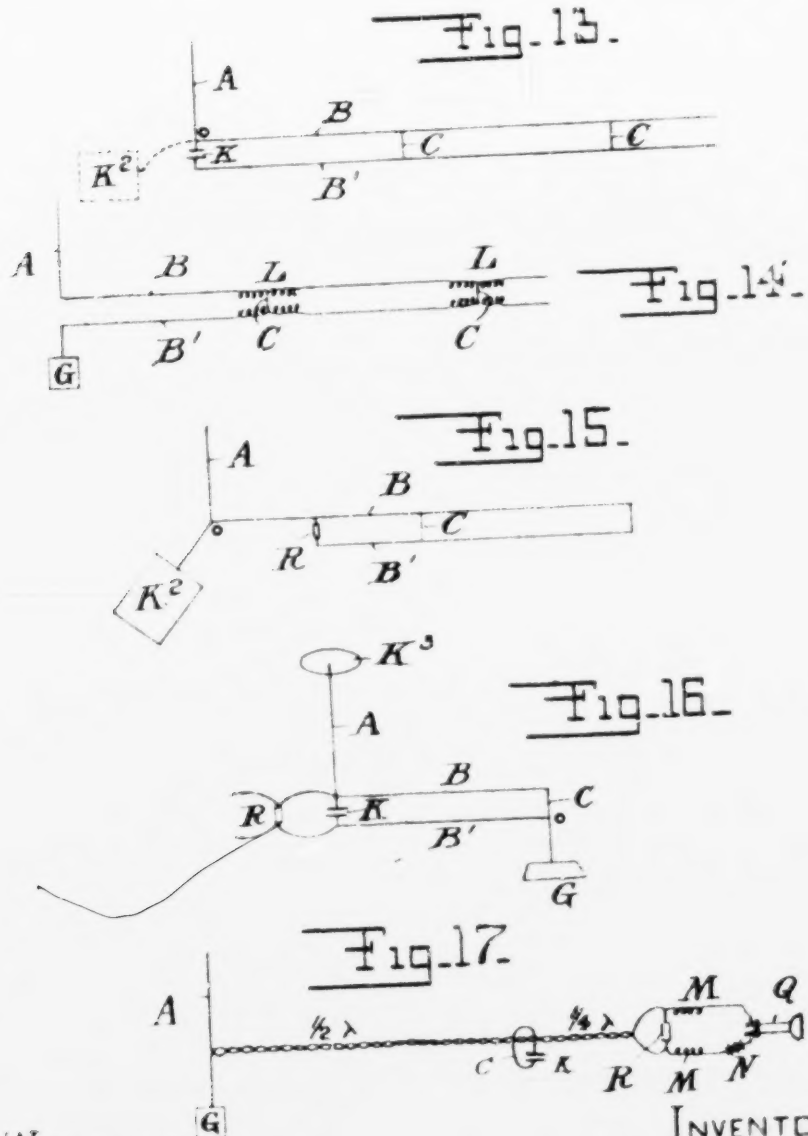
PATENTED JUNE 9, 1903.

No. 730,246.

L. DE FOREST.  
SPACE TELEGRAPHY.  
APPLICATION FILED MAR 9, 1903.

5 SHEETS—SHEET 4.

NO MODEL.



WITNESSES:  
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NO MODEL

5 SHEETS-SHEET 3

Fig. 18.



Fig. 19.

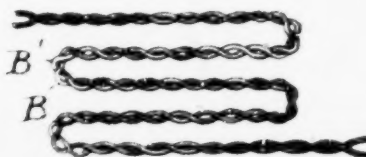


Fig. 20.

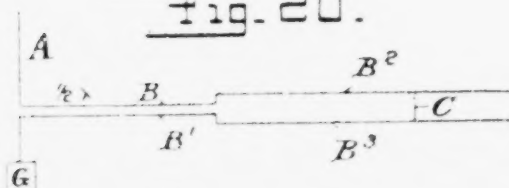


Fig. 21.

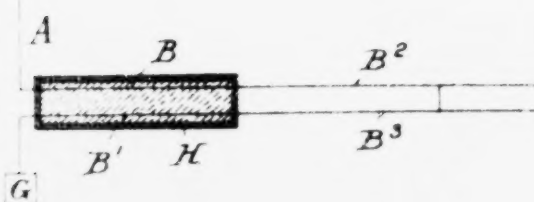


Fig. 22.

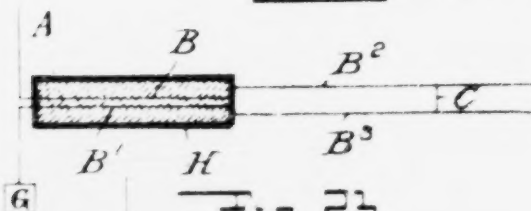
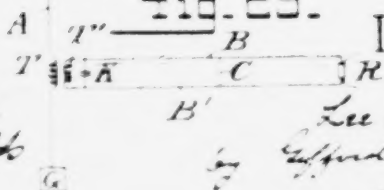


Fig. 23.



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# UNITED STATES PATENT OFFICE.

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## SPACE TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 730,248, dated June 9, 1903.

Application filed March 8, 1902. Serial No. 97,239. No model.

*To all whom it may concern:*

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New Haven, in the county of New Haven, State of Connecticut, have invented a new and useful Improvement in Space Telegraphy, of which the following is a full, clear, and exact description.

My invention relates to improvements in those systems of electric signaling between two points which use natural media for the transmission of the electrical impulses and which are ordinarily referred to as "space" or "wireless" telegraphy.

My invention comprises certain novel features, which will be herein described, and particularly pointed out in the claims.

In the drawings accompanying herewith I have shown and in the specification have described numerous forms of apparatus in illustration of the manner of applying my invention to use and of adapting it to different circumstances and requirements. I am aware, however, that it may be embodied in other forms, and do not, therefore, wish to be understood as limiting myself to the forms herein shown, but seek to claim my invention in any form in which it may be embodied. The scope of my invention is to be determined by a reference to the accompanying description and particularly to the claims attached thereto.

The accompanying specification is a description of my invention as embodied in the figures of drawings given.

Figure 1 shows an apparatus embodying my invention used as a sender. Fig. 2 shows diagrammatically a simple form of apparatus containing my invention employed as a receiver. Figs. 3 to 7, inclusive, show modified forms, which by the use of either a responder or an energizing device may be used either as a sender or as a receiver. Figs. 8 to 11, inclusive, show my invention in various modifications employed as senders. Figs. 12 to 23, inclusive, show forms of my invention employed as receivers. Figs. 24, 25, and 26 show other arrangements of parts employed in my invention.

While I have shown and described some arrangements employed as receivers and others

as senders, and while some of the arrangements shown are better adapted for the one use than for the other, there is in general nothing to forbid the employment of any of the arrangements shown in either capacity by substituting either a responder or an energizing apparatus for whichever of these is shown.

In systems of space or wireless telegraphy now being employed a failure to attain the efficiency or power desired is largely due to the fact that the electrical waves emanating from the sending device are rapidly damped or decreased in intensity or amplitude. In other words, while the maximum intensity or amplitude of the waves may be satisfactory their persistence is unsatisfactory, as they rapidly fall in amplitude to nothing. In consequence of this their energizing action upon the receiving antenna being repeated but a few times does not have the cumulative energizing effect that a much weaker impulse would have if repeated a greater number of times. The effect is comparable to the effect produced upon a vibrant body, as a piano wire, by its note being sounded loudly for a very short time or less loudly for a much longer time.

I have discovered a means whereby I am able to produce with each signal a longer and better sustained series of waves, the same means also lending themselves readily to use in the receiver, in which use they have special and marked advantages.

It is a well-known fact that if two adjacent and parallel wires of equal length are connected each with a terminal of any form of apparatus producing electrical oscillations of high frequency the charges in said wires at any point of their length are of exactly equal intensity and of opposite phase. The currents flowing in these two wires are also at corresponding points equal in amount and flow in opposite directions. If these wires are the equivalent of one-quarter or any multiple thereof of the wave length of the electrical oscillations transmitted thereto, very efficient reflection occurs at the ends of these wires, with the result that stationary or standing waves are set up, caused by the incident and reflected oscillations. The system then divides up into quarter or half wave lengths

with nodes and loops symmetrically situated on each wire. As the nodes of these electrostatic stationary waves in a conducting body, as a wire bridge, may be placed across both wires without seriously interfering with the action beyond. At a distance of one-quarter wave length from said nodes loops are formed, at which points the maximum possible difference of potential between the two parallel wires exist. Such a system of parallel conductors is known in the art as the "Lecher" system of wires. The phenomena involved in this system have been worked out theoretically, notably by Lord Rayleigh, Drude, Heaviside, and others, and have been set forth by these and other people, as in the following instances. By E. Lecher, in *Wiedemann's Annalen*, No. 41, page 850; Barton and Bryan, *Phil. Mag.*, August, 1897; E. Marx, *Wiedemann's Annalen*, No. 11, 1898; Lord Rayleigh, *Phil. Mag.*, No. 43, 1897; E. Lecher, *Wiedemann's Annalen*, No. 42; Heaviside, *London Electrician*, April 9, 1897; Bjerknes, *Wiedemann's Annalen*, No. 55, page 121. As has been pointed out by investigators, what is known as the "wire and sheath" return, consisting of a wire surrounded by a coaxial tubular conductor insulated therefrom, is only a special form of the Lecher system and is subject to the same laws as the simple system. The general theory has shown that in this Lecher system of conductors, or for a wire and its coaxial return, the self induction and capacity are evenly distributed and are reciprocals per unit length of the system—that is to say, the capacity and self induction cancel each other as far as the dimensions of the wire are concerned, that the period of vibration is independent of the distance between the two wires and of their diameters. Such a system of conductors is known in the art as a "distortionless" circuit. The velocity of propagation thereon for high frequency oscillations is approximately that of light. For example, this is the velocity when the resistance per unit length is negligible compared to the self induction and when this self induction is the reciprocal of the capacity per unit length. These conditions are satisfied when the wires are less than one-half millimeter in diameter and less than 100 meters long.

The formula for the self induction per unit length of the Lecher system is  $L = \log \text{nat } d/r$ , where  $d$  is the distance between the centers of the two parallel wires and  $r$  their common radius. The expression for the capacity per unit length is the exact reciprocal of the above, or  $C = 1/L$ , hence the remarkable property of the Lecher system that the velocity of the propagation of an electric wave along its length is independent of the size of the wires or of the distance between their centers, and this velocity comes out as equal to the velocity

of light. This being the case it will be at once understood how the period of any section of a Lecher system embraced between two consecutive bridges is a function of the length between said bridges alone. Hence in arrangements shown in Figs. 20, 21, 22, and 24 the velocity of propagation along section B B is identical with that along section B' B', and if the length of these two sections is the same the period of oscillation of each section will be the same, but although the product ( $L \cdot S$ ) be the same for both,  $L$  is small in B B and large in B' B', while  $S$  is large in B B and small in B' B'. Now the relative quantities of electromagnetic and electrostatic energies depend wholly on the ratio of  $L$  to  $S$ . Where self-induction is large and capacity small, we will have a greater portion of the total energy as energy of inertia or momentum. Where capacity is large and self induction small, we will have a greater proportion of the total energy as energy of elasticity. Hence in passing from B B to the section B' B' we will have a transference of energy from the electrostatic to electromagnetic—for example, two opposite charges are traversing B and B'. When these pass upon B' and B', respectively, where the capacity is less, their potential difference must be increased, and vice versa.

On account of losses from resistance, leakage, and imperfect reflection at bridges or open ends in such a system of parallel wires as is here described the stationary waves set up therein are never perfect, and therefore absolute nodes are never found in practice, although with suitable reflecting devices the approximation thereto when a slowly-damped wave train is transmitted is very good. We get instead points of maximum and minimum potential difference and of current, whose magnitudes are dependent on the coefficient of resistance, leakage, and reflection.

Ordinarily the order of magnitude of the energy involved in the two sets of waves (the electrostatic and electromagnetic) is the same, and if the parallel wires were infinitely small in diameter the magnetic force must equal the electric, and the greater the surface the loss becomes, the magnetic force relative to the electric, the one increasing as the other decreases.

The characteristics and advantages of the Lecher system are:

(a) It is to a high degree a resonant vibrator—that is, it has a very marked period of its own and is very little responsive to oscillations of any other frequency than its own.

(b) It is a poor absorber and consequently a persistent vibrator, persisting for some time in its vibrations once they are set up, therefore producing a long wave-train and damping slowly. This is because most of the lines of force lie in the space between the two conductors and the radiation losses are therefore small except when a radiator is attached.

One authority states that the observable magnetic effect from a Lecher system, even strongly excited, does not extend beyond three centimeters from the parallel wires.

(c) By reason of the stationary waves set up higher potentials are obtained than are otherwise possible.

(d) The nodes and loops of these stationary waves are fixedly located, thus enabling connections to be made with the wires at any phase of the wave desired.

(e) The system may be easily and accurately tuned to any frequency desired.

(f) It is simple in its mathematical and theoretical aspects. Its constants are easily calculated and regulated, so that the dimensions of a system for securing definite results may be readily predetermined. This has not yet been satisfactorily done for other forms of apparatus employed in connection with currents of very high frequency, such as are employed for space signaling. The velocity of transmission in a simple Lecher system is approximately equal to that of light. Therefore the wave lengths or frequency may be readily determined and exactly defined. A brief description of the phenomena and laws obtaining in such a system of parallel conductors has been given by me in the *American Journal of Science* for July, 1899.

I have discovered that these characteristic features of the Lecher system of wires render them especially adaptable for use in wireless telegraphy. In their application they are flexible, being adaptable to various modifications as may be required by the various circumstances, as the type of transmitter or receiver employed and the practicable dimensions of the apparatus, as the height and character of the upright wire.

In the figures of the drawings accompanying herewith I have shown various modifications in which the Lecher wires are employed, some representing the sending apparatus and others the receiving apparatus, although in general either a sending or a receiving apparatus may be employed with either.

In Fig 2 I have shown Lecher wires B B in use with a receiver, one wire, B, connected with an upright wire or antenna A and the other, B, connected with the ground G or other capacity. The equivalent length of the upright wire or collector A is one-quarter of the wave length of the natural oscillation to which the system is attuned. At a distance of one-half wave length from the foot of the upright, as at 1, occurs the first node, and if the wires are long enough other nodes are formed separated by the same distance as the node 2 shown in the figure. At these nodes the wires may be connected by no-resistance bridges, as C C, without destroying or seriously affecting the oscillations or the propagation of the waves. These bridges may also be grounded, as shown by dotted lines at G in Fig 4, without affecting the period of vibration.

If the wires be continued one-quarter wave length beyond the last node, as shown in Fig 2, a loop of electrostatic force will be formed by the open-end reflection. At such open ends all the energy of the system is electrostatic. Therefore, as the sensitive device operated by a difference of potential across its terminals, such as a coherer or other responder, may be inserted most advantageously at a static loop, these ends form a desirable location for such a device. The dotted lines D, Figs 2 and 3, indicate the position and intensity of such waves in the system. In Fig. 2 a responder is shown at R inserted between the open ends of the Lecher wires. Such a device may, however, be inserted wherever an electrostatic loop occurs. A sensitive device operated by current or electromagnetic stationary wave, such as a bolometer, or thermo element, should be placed at the loop of an electromagnetic wave. The electromagnetic waves do not coincide in location with the electrostatic waves, but, as is well known in the art, are separated along the wire by ninety degrees or by a quarter-wave length. The relative positions of these different waves are shown in Fig 3, in which the dotted line D represents the electrostatic wave, and E the electromagnetic wave. A bolometer or other device operated by current or electromagnetic waves may be located at any loop of an electromagnetic wave. Such a device is shown at R in Fig 3.

Since the simple antenna A is a strongly-damped vibrator and the system of parallel wires attached at its base a weakly-damped or strongly resonant vibrator, it sometimes results that a violent oscillation received by the antenna, if strongly damped, may excite in the parallel conductors vibrations having the distinctive period of said conductors, regardless of the period of the exciting impulse. Were this exciting impulse, however, a long wave-train, interferences in the parallel wires would arise and the effect above described could not obtain. Conversely, if this long wave-train have the frequency to which the wire system is attuned this latter would be violently excited. Thus by regulating the sensitiveness of the receiving device R response to oscillations other than those to which the system is attuned may be prevented.

In Fig 4 the wire and sheath return is shown, wherein, as in the Lecher wires, the self-induction and capacity are also evenly distributed. This, as shown, consists of a central conductor, as a wire B, and an outer tubular conductor B surrounding it. These two conductors may be connected at the location of electrostatic nodes by bridges, as C. As shown in Fig 4, the waves travel upon the outer surface of the inner conductor and back on the inner surface of the tubular or outer conductor. The connections, however, of the antenna and the ground may be reversed, or we may regard the annular space between the two conductors as the region within which the

other vibrations are confined. A responder, sender, or other equivalent device is shown as located at R, the same being at an electrostatic repel.

In Fig. 5 the wires B and B' are simple Lecher wires, such as described in connection with Fig. 2. The antenna A of Fig. 2 is however replaced by the conductive cylinder A' connected with wire B and the central wire A' which latter is connected with the wire B'. These form a wire and sheath return system employed as a radiating or a receiving antenna. This is only an exemplification of the wire and sheath return employed as an antenna. When used as a radiating antenna, an antenna connection made to the inner conductor axis the field of force is divided part between the exterior of conductor A and the ground and the greater portion concentrated in the annular space between the two conductors A and A'. This arrangement results in a concentration of force, only a small portion of the energy being radiated outward at each oscillation, but these oscillations are continued for a considerable time. When used as a receiver, the sensitive device at R is the type of the responder, should be located at a static repel, as shown at R.

In Fig. 6 the conductors B and B' are the simple Lecher conductors, one of them being connected with the ground G. The simple antenna is replaced by two plates A and A' which may be considered simply as an extension of the Lecher conductors. If the plates of these two plates be parallel and adjacent, the greater part of the energy is concentrated in the field therebetween. The region lying in front of A will at one instant be occupied by lines of force representing a positive wave, and that behind A' will at the same instant be occupied by lines of force representing a negative wave. The respective lines of force radiating from these plates are constantly changing their sign, radiating from one to the other, but in every way of opposite sign in the respective regions and at points the same number of wave lengths distant from their respective plates. In the region of the two parallel plates the oscillation will be comparatively slow, the waves of radiations from both plates. The waves in this region will be of opposite sign, and a receiver located in such region will be little affected, because the fact that one plate, as A, is grounded results that the waves from the other, A', will be of opposite sign, thus preventing that a receiver located in which the intensity of the force, the magnitude and power of force, is far slower than in the plates and the air. The plate A being connected to the earth there will be a more of potential between this unit and the earth, and therefore more concentrated lines of force. But these reasons radiations are of comparatively slight. The direction of strongest propagation is therefore away from A, and as the plate A tends to draw in the lines of force which proceed in its

approximate direction the direction of strongest propagation is perpendicular to its plane. This feature enables the direction of propagation of the effective energizing or signaling waves to be in a measure controlled or directed or, in other words, provides for the maintenance of a neutral zone or zones. If these plates be mounted so as to be rotatable upon a common axis, the position of these neutral zones may be controlled, and the same apparatus may thus be utilized for signaling in any direction desired, while approximately non-effective in other directions. This fact may also be utilized in preventing interference between different apparatus located in a common field of energy which would otherwise interfere with each other. When used as a receiving antenna, the rotative plates may be utilized for receiving messages coming from a given direction, while in considerable measure neutralizing or cutting out the waves coming from other directions. It follows that if the device has a direction of maximum propagation and directions of minimum or no propagation it will conversely have directions of maximum and minimum sensitiveness to the reception of waves, from which it follows that if more than one series of waves are coming in it will be most responsive to those which come from its direction of maximum efficiency, and also by turning the plates to the position where the message is most clearly received the plate A' will be found to be facing the direction from which the impulses are received. In this way the direction from which a signal comes may be approximately told.

If it is desired that both antennas be charged alike instead of oppositely, as may at times be desirable to secure increased radiating or collecting power, this result may be obtained by inserting between the base of one and the leg of the Lecher system connected thereto a retarding device, such as a coil or length of wire equivalent in length to one-half wave length of the oscillation for which the system is attuned. Such a coil is shown at E in Fig. 7. If used as a receiver, a wave traveling down the antenna A' will be delayed by its passage through the coil E by a time equal to one-half its period, and so will enter upon its arm of the Lecher wires at a time when a wave of opposite sign enters upon the other arm of the Lecher system. Thus the necessary condition of waves of opposite sign in the Lecher system is fulfilled.

In Figs. 8, 9, 10, and 11 means are shown for exciting any apparatus or for transmitting thereto the electrical oscillations necessary when employed as a sender. These figures do not show all the means which may be employed for this purpose, but are given as illustrative of well-known means which adapt themselves to this use.

In Fig. 8 a "static" method of charging is shown. The parallel or Lecher wires are shown as of only one-half wave length. Inserted in the bridge between their ends is a

denser K. In shunt around this condenser are a spark gap S and the secondary coil T of a transformer T T. When this condenser is charged to the breaking down point of the spark-gap S, a discharge occurs at this point, and this serves as a connecting-bridge between the parallel wires, and these wires are set in vibration as a Lecher system. Part of the energy is reflected back at O and O', forming stationary waves with nodes at O and O'. A part goes into the upright conductor or antenna A and is radiated outward.

In Figs. 9, 10, and 11 the Lecher system is charged inductively—that is, the secondary T of the transformer is in the circuit of the Lecher system and oscillates therewith, while in Fig. 8 it is not in such circuit and does not enter directly in its oscillations. In fact, in Fig. 8 the transformer may be replaced by any source of electrical energy giving the requisite potential.

In Fig. 9 the parallel wires are shown as equal to one quarter wave length and the coil T, forming the secondary of the transformer, is equivalent to one half wave length. The primary coil T of this transformer, as a matter of course, with condenser K and spark gap S. This primary system is charged from any suitable source of energy E. It is noted here that the self-induction of the primary coil T and the capacities K, being chosen that the natural period of oscillation of this primary system is equal to that of the adjoining Lecher system.

Fig. 10 shows a system essentially the same as that shown in Fig. 9, except that a condenser K is connected to the Lecher wires at the static loop. A condenser so located is the equivalent of a certain length of parallel wires, so that a system containing a condenser differs with a period of oscillation longer wires or, conversely, the length of wire necessary for a system of a given period. The electrostatic capacity of such a system also depends somewhat upon its location in the stationary waves, it being most effective when located at a static loop, i.e., at a point where the potential difference across its terminals is maximum.

It has been observed that a capacity located near a loop exerts a greater or less distorting or absorbing effect upon the wave system, according as it is located near an electrostatic loop or near a node. If near a loop the potential difference across its terminals is greater. Hence the quantity of electricity capable of being stored thereby is correspondingly greater, and the effect of this storing up at such a point is proportional, therefore, to the location of the condenser in the Lecher system. In other words, while the absolute capacity is independent of this location, its effective or equivalent capacity is dependent thereon.

The use of a condenser as a means for adjusting the period or equivalent length of a

system, for which purpose it is most effectively placed adjacent a static loop, should be distinguished from its use in a bridge to prevent direct connection between the wires, as is shown at K in Figs. 1, 17, and 25, where it is located at a static node. In this position it acts as a bridge, while at the same time insuring the transfer to the system beyond the bridge of a larger percentage of the energy than would a plain wire bridge or direct connection. It is, however, not altogether devoid of an effect in lengthening the period of the system. Condensers may be employed for both of these purposes in the same system, as is shown in Figs. 1 and 25.

Fig. 11 shows the Lecher wires cut at static loop and a condenser inserted in such cut, between the Lecher wires and the secondary terminals of the transformer. Here also the armatures of the condenser behave as the equivalent of a certain length of wire, this relation depending upon the amount of surface in the condensers and the distance between the armatures. This affords a ready means of attuning the system, by changing the distance between the armatures of the condensers. Since the maximum potential of opposite sign occurs at the terminals of the secondary T of the transformer, the middle point of the cut must be one of zero potential and may therefore be grounded as shown at G, without interrupting the action of the system.

If the devices shown in Figs. 10 or 11 are used as receivers, the transformer coils T and T' should be reversed in arrangement, as shown in Fig. 12, the low potential coil T being connected to the Lecher wires, and the receiving instrument or responder R may be substituted for the spark gap S. The same necessity arises in this case as in the sender for tuning alike the two circuits shown.

In the receiver it is not always necessary to ground any point of the Lecher system of wires. In Fig. 13 if a node be formed, as at O, at the base of the upright A stationary waves will be set up in the parallel wires as before, and in the absence of any earth connection the energy of the oscillations has no opportunity to leak away and must be consumed only in heat and reflection losses in the receiver instruments. To insure the formation of a node at O, a low capacity coil, C, may be connected at this point. If a capacitor, as K, be connected at O between the two wires, its capacity should be small, as a condenser at this point in the system shown acts as a bridge.

In Fig. 14 is shown a method of reducing the actual length of wires required to form the equivalent of the proper wave length, which consists in inserting coils L, L', in the wires of the Lecher system. These coils should be inserted at loops of current where the inductive or impedance effect will be maximum. If the Lecher wires are to be bridged, these bridges should connect the middle points of two corresponding coils, as shown at C.

In Fig. 1 I have shown a system which employs both inductance coils L and a condenser K as lag producing or period adjusting devices. I also show a condenser K employed as a bridge at the base of the antenna. The bridge C, which connects the two inductance coils, might be of the same form. The wave producing device is of the same construction and is connected with the system in the same manner as that shown in Figs. 9 and 16.

The use of bridges at the nodes of wires of more than one half wave length and placing the receiving instrument beyond said bridge or bridges has one advantage. The bridge, if grounded, will have the effect of leading off or grounding waves of such length that their nodes are formed elsewhere and will thus screen or protect the responder or equivalent receiver from the effect of all waves except those which are of the length for which the apparatus is adjusted. Upon waves of the proper length the bridges produce but little effect of this character.

It is not always necessary that the two parallel or Lecher wires be of the same length. Fig. 15 shows an arrangement in which the responder R is located at a static loop of the wires and one quarter wave length removed from the base of the upright wire. At this point in the lower wire we have a static loop formed by open end reflection. The node at C may be connected to earth or to a capacity K.

In all the foregoing figures the upper end of the upright wire has been considered as the location of the static loop, of which the node was at the base one quarter wave length below it. If a body having a large capacity, such as K' in Fig. 16, be located at the top of the upright wire or antenna, its capacity may be such as to produce reflection in the waves oscillating in the upright conductor equivalent in sign to the reflection obtained at a bridge in the Lecher wire system. This means that a static node will be formed at this point with a loop at the lower end. The earth connection then should be at a point along the parallel wires one quarter wave length distant from the base of the upright wire or antenna where the second node will be located. As the capacity K' makes a static node at the top of the antenna where ordinarily is a static loop, the location of the condenser K corresponds with a static loop. The condenser K of Fig. 19 is also at a static loop. In both cases the condenser represents or absorbs a certain amount of the wave length and is located as to shorten the apparent wave length of the Lecher system. The condenser K in Fig. 1 shortens the length necessary in B B, and consequently also shortens the length necessary in A to still keep A in resonance with the attached Lecher system. The responder may be located, as shown, in shunt around the condenser.

In Fig. 17 is shown a convenient form of

using the Lecher wires. Here the two wires which are insulated, are twisted together, forming a twisted pair, the distance between them being regulated by the thickness of the insulation. It is desirable that the pitch of the twist be not too steep. The twisted pair is well adapted to use upon a spool or coiled in any other manner which may be desirable to economize space or to secure portability. If the two simple parallel wires untwisted were coiled upon a spool, with convolutions parallel and near together, interference by induction between adjacent convolutions would arise, but when closely twisted such adjacent convolutions of the coil if not too close together will not interfere with one another. In any considerable length of the convolution one wire will first be adjacent to another carrying current of like sign and then to one carrying current of opposite sign, so that for any considerable length of wire the inductive effects from the two wires in the convolutions adjoining will be neutralized. In practice I have successfully used such wires twisted with a pitch equal to three turns to the inch wound upon a spool about three inches in diameter with successive turns separated about an eighth of an inch. Their use is not, however, limited to even a near approximation to the above proportions, which are given only to show what has been found successful without any intention of limiting myself thereto.

So far as I am aware such a method of embodying the Lecher wires and of utilizing their advantages has never before been used. It retains practically all the theoretical advantages of the straight parallel wires embodied in a compact form, which makes the apparatus portable and practical. Wherever in the accompanying drawings or description straight Lecher wires are shown or described, it is to be understood that the twisted pair, as above described, may be substituted, either coiled, as shown in Fig. 18, or disposed in any suitable way—for instance, as in Fig. 19. Bridges, a condenser, or any other device such as described in connection with the previous features may be inserted as desired and are controlled in location and action by the same principles as apply to the simple straight wires. In Fig. 17 a responder R, choke coils M M, a battery N, and a telephone Q, or other indicating instrument are inserted in a local circuit after the manner common in wireless telegraph apparatus.

As shown in Fig. 17, the responder is placed across the open end of a loop and one quarter wave length distant from the responder, and one half wave length distant from the upright A is or may be placed a bridge C. To avoid shunting the local circuit about the responder, which would occur if a no resistance bridge or a metallic connection were used, a condenser K is placed in the bridge, which condenser is of sufficient capacity to act as a no resistance bridge for the Hertzian oscillation, while forming

ing an effective interruption for the local current.

When employed in the sending device, it may be desirable for purposes of insulation to immerse the entire system in oil.

In Figs. 20, 21, and 22 are shown constructions by which the potential may be simply and effectively transformed either to raise or lower it, as desired. The principle therein illustrated may be employed either in the sender or the receiver, but is more especially recommended for use in the receiver.

The general theory shows that the mutual induction of the Lecher wires decreases as the two parallel wires are brought closer together, becoming zero for the wires in actual contact, and that conversely the capacity of the system is thus increased. Consequently if one system of such parallel wires, as B B', Fig. 20, of length equivalent to one-half wave length of the vibration transmitted be added to another system, as B<sup>2</sup> B', of the same period of electrical vibration, but having its two parallel wires farther apart, then this second system B<sup>2</sup> B' may take up the impulse transmitted from the first system unaffected as to its period of vibration, yet transformed to a wave of higher potential, but of correspondingly diminished magnetic energy or current. On the same principle if the first-mentioned system, say of one-half wave length—have for the dielectric between its two parallel wires a substance of higher specific inductive capacity than that between the two parallel wires of the second system then the capacity of the first system per unit length is greater than that of the second system. The electrical energy will therefore be transferred from the first to the second system, altered in its relative proportions of electrostatic and electromagnetic energies. So in the arrangement last described the transformation will be, as before, to step up the potential and to diminish the currents flowing in the second system. Such a system is illustrated in Fig. 21, in which the wires B B' are parallel throughout their length, but the first half wave length from the upright is inclosed in a casing H, containing oil. Thus I employ one pair of parallel wires—for example, of length equivalent to a half wave length of the vibration transmitted—immersed in and separated by an oil, and connected to one end of this system another system of parallel wires of a length also equivalent to one-half wave length, but equally separated by air or by a dielectric of small specific induction capacity, and thus obtain between the two wires of this second system a higher difference of potential than existed between the wires of the first system. Such immersion in a fluid may result in a change in the wave length required for a given period. In Fig. 22 a combination of both plans is shown, the first half wave length B B' being immersed in oil and also having its wires closer together than the second half

wave length B<sup>2</sup> B', which are separated only by air.

When desirable to still further increase the self-induction of one of such systems of parallel wires as I have described, I may insert at corresponding points in each of the two wires inductive or momentum coils of suitable impedance and construction, as shown at I, I', Fig. 23. Similarly, to increase the capacity of the other system I may attach to each of the parallel wires thereof an armature of a condenser of suitable area, as shown at K, Fig. 24.

Such combination of systems as I have here described thus affords a step-up or step-down device entirely differing from "transformer coils," ordinarily so called, a device novel and useful in its application to the art of space telegraphy.

In all the figures so far mentioned the antenna is shown as directly connected with what may be called the "resonant" conductors—that is, with the parallel conductors which produce the stationary waves. This is, however, not a necessity, as the resonant conductors and the antenna may contain devices in circuit therewith whereby the wave effect is transmitted inductively. Such a construction is shown in Figs. 25 and 26, in which T, T' represent the two coils of a transformer or induction coil, one being in the circuit of the resonant conductors B B' and the other in the circuit of the antenna. When applied to a receiving device, the coil T is the primary coil and T' the secondary. When applied to a sending device, they would be reversed in position or function. This method of connecting the parallel conductors and the antenna may be employed in the forms illustrated in the other figures. As shown in these figures, the conductors extending each way from the center of the coil T to the first bridge C' or the point where the first node is formed are each the equivalent of a half wave length, the condensers K, if employed, being taken into consideration. The condenser may, however, be dispensed with and its effect produced by employing some other form of lag-producing device, such as inductances or coils, after the manner illustrated in Fig. 14 or the conductors B B' lengthened to the proper amount. The indirect or inductive method of connecting the antenna with the parallel Lecher conductors may be employed generally with the same result as in the other figures in lieu of the direct connection shown therein. Wherever in the description or claims one form of connection is specified, I am to be understood as stating of the other form to be an equivalent therefor.

In Fig. 25 the last system with which the receiver circuit is connected is inductively connected with the other systems after the manner shown in Fig. 12.

In Figs. 25 and 26 condensers K, K' are

shown as placed in and forming part of the conductive systems after the manner shown in Figs. 11 and 12.

In Fig. 26 the antenna is directly connected with the ground G and inductively with the resonant system by the coils T T', as described in connection with Fig. 23.

In the foregoing description I have endeavored to describe such modifications and variations in the apparatus which may be employed as will make clear the principles of my invention without intending to show all the modifications which are available or feasible. Other combinations will suggest themselves to one familiar to the art.

I am not to be understood as limiting myself to the forms or exact combinations of various elements shown, as I am aware of other modifications and combinations which might be employed. The further multiplication of the drawings seems, however, to be unnecessary, as those given serve to clearly set forth the principles of my invention.

The scope of my invention is to be determined by reference to the claims terminating this specification, in which the omission in any claim of any element or the failure to include therein any qualification of an element is to be understood as a distinct statement that such element or qualification is not essential to that particular combination.

Having thus fully described my invention, I claim as new and desire to secure by Letters Patent—

1. In an apparatus for space telegraphy, in combination, an antenna and two parallel conductors adapted to act inductively upon each other, one of which is electrically connected with the antenna, said conductors being each equivalent to a multiple of a quarter-wave length.

2. In an apparatus for space telegraphy, in combination, an antenna and a plurality of parallel conductors cooperating therewith and adapted to develop stationary electrical waves.

3. In an apparatus for space telegraphy, the combination with an antenna of two conductors each equivalent in length to a multiple of a quarter-wave length and adapted to the production in each other of stationary electrical waves.

4. In space telegraphy, in combination, parallel conductors adapted to the production of stationary electrical waves, and an antenna connected to one of the conductors whose natural period of vibration corresponds to that of the parallel conductors.

5. In space telegraphy, in combination, parallel conductors adapted to the production in each other of stationary electrical waves, and an antenna connected at a node of said waves to one of the conductors and having a natural period of vibration corresponding to that of the parallel conductors.

6. In space telegraphy, in combination, plu-

ral conductors adapted for the production of stationary electrical waves, bridges connecting said conductors at points corresponding with the nodes of said waves, and an antenna connected with one of the conductors.

7. In space telegraphy, in combination, plural conductors adapted for the production of stationary electrical waves, bridges connecting said conductors at points corresponding with the nodes of said waves, ground connections for said bridges and an antenna connected with one of the conductors.

8. In space telegraphy, in combination, a plurality of mutually inductive conductors adapted for the production of stationary electrical waves, an antenna connected to one of said conductors and a receiver located at a loop of said stationary waves.

9. In space telegraphy, in combination, a plurality of mutually inductive conductors adapted for the production of stationary electrical waves, an antenna connected to one of said conductors at a node of said waves, and a receiver located at a loop of said waves.

10. In wireless telegraphy, the combination with an antenna, of two conductors of substantially uniform separation, one of said conductors being connected with the antenna.

11. In wireless telegraphy, the combination with an antenna of two conductors of substantially uniform separation, one of said conductors being connected with the antenna, and tuning or period adjusting devices connected with said conductors.

12. In space telegraphy, in combination, an antenna, two conductors adapted to the production of stationary waves, one of said conductors being connected with the base of the antenna and a condenser between the base of the antenna and the other of said conductors.

13. In space telegraphy, in combination, an antenna, two parallel conductors connected at one end and having a condenser between their other or open ends, and an antenna connected with the open end of one conductor.

14. In space telegraphy, in combination, an antenna, two parallel conductors connected at one end and open at the other, and an antenna connected to the open end of one conductor, the joint lengths of said conductors being equivalent to a multiple of one-quarter of the wave length for which the antenna is adapted.

15. In space telegraphy, in combination, an antenna, a conductor consisting of a wire and sheath return having one end of the sheath connected with the antenna, and the corresponding end of the wire connected with a capacity.

16. In space telegraphy, in combination, an antenna, a conductor consisting of a wire and sheath return having an end of one of said members connected with the antenna.

17. In space telegraphy, in combination, an antenna, a conductor consisting of a wire and sheath return having one end of one of said

members connected with the antenna, said wire and sheath return being equivalent in length to a multiple of a quarter-wave length.

18. In space telegraphy, in combination, an antenna, a conductor consisting of a wire and sheath return connected with a capacity, said wire and sheath return being equivalent in length to a multiple of a quarter-wave length.

19. In space telegraphy, the combination with parallel conductors forming a resonant system, an antenna connected with one end of said system, and means connected with the said conductors for the production therein of stationary electrical waves, of a capacity connection between said conductors adapted to lengthen their period of vibration.

20. In space telegraphy, the combination with parallel conductors forming a resonant system, an antenna connected with one end of said system, and means connected with the said conductors for the production therein of stationary electrical waves, of a capacity connection thereto adapted to lengthen their period of vibration.

21. In space telegraphy, the combination with parallel conductors forming a resonant system, an antenna connected with one end of said system, and means connected with the said conductors for the production therein of stationary electrical waves, of a capacity connection between said conductors adjacent to a static loop of said waves.

22. In space telegraphy, the combination with an antenna and two parallel conductors adapted to form a resonant system, one of which conductors is connected with the antenna, of condensers inserted between said parallel conductors.

23. In space telegraphy, the combination with an antenna and two parallel conductors adapted to form a resonant system, one of which conductors is connected with the antenna, of condensers inserted between said parallel conductors at points corresponding substantially with the loops of the electrostatic waves therein.

24. In space telegraphy, the combination with an antenna and two parallel conductors adapted to form a resonant system, one of which conductors is connected with the antenna, of lag-producing devices connected with such parallel conductors.

25. In space telegraphy, the combination with an antenna and two parallel conductors adapted to form a resonant system, one of which conductors is connected with the antenna, of lag-producing devices connected with such parallel conductors, and means for adjusting said devices to control the amount of lag produced thereby.

26. In space telegraphy, the combination with an antenna and two parallel conductors adapted to form a resonant system, one of which conductors is connected with the antenna, of condensers connected with said conductors and having their poles adjustable toward and from each other.

27. In space telegraphy, in combination an antenna, parallel conductors connected therewith and adapted to the production of stationary waves, and a condenser between the ends of said conductors.

28. In space telegraphy, in combination, an antenna, a conductor connected therewith and adapted to the production of stationary waves, a condenser between the ends of said conductor and a wave-indicating device connected in shunt about said condenser.

29. In an apparatus for space telegraphy, in combination, an antenna and two parallel and mutually-inductive conductors, one of which is electrically connected with the antenna and a wave-indicating device between said conductors.

30. In an apparatus for space telegraphy, in combination, an antenna, two parallel and mutually-inductive conductors one of which is electrically connected with the antenna, said conductors being each equivalent to a multiple of a quarter-wave length, and a wave-indicating device connecting said conductors at a point equivalent to a multiple of a quarter-wave length distant from said antenna.

31. In an apparatus for space telegraphy, in combination, an antenna, a plurality of parallel conductors cooperating therewith to develop stationary electrical waves, and a wave-indicating device placed in the field of said waves substantially at a loop thereof.

32. In an apparatus for space telegraphy, the combination with an antenna, and two parallel conductors each equivalent in length to a multiple of a quarter-wave length and adapted to the production of stationary electrical waves, and a wave-indicating device connecting said conductors at a point corresponding substantially with loops of said waves.

33. In space telegraphy, in combination, a plurality of conductors adapted for the production of stationary electrical waves, bridges connecting said conductors and located substantially at nodes of said waves, an antenna connected with one of the conductors and a wave-indicating device connected with said conductors substantially at a loop of said waves.

34. In space telegraphy, in combination, a plurality of conductors adapted for the production of stationary electrical waves, an antenna connected with one of the conductors, bridges connecting said conductors and located substantially at nodes of said waves, and a wave-indicating device connected with said conductors substantially at a loop of said waves and beyond a bridge from the antenna.

35. In space telegraphy, in combination, an antenna, a conductor consisting of a wire and sheath return having the wire and sheath connected one with the antenna and the other with a capacity and a wave-indicating device connected between the wire and sheath.

36. In space telegraphy, in combination, an antenna, a conductor consisting of a wire and

sheath return, one of which is connected with the antenna and a wave-indicating device connected between the wire and its sheath.

47. In space telegraphy, in combination, an antenna, a conductor consisting of a wire and sheath return, one of which is connected with the antenna and a wave-indicating device connected between the wire and its sheath, at a point corresponding substantially with the loop of the waves in said conductor.

48. In space telegraphy, in combination, an antenna, a conductor consisting of a wire and sheath return, one of which is connected with the antenna, said wire and sheath return being equivalent in length to a multiple of a quarter-wave length, and a wave-indicating device connected between the wire and its sheath.

49. In space telegraphy, the combination with parallel conductors, means connected therewith for the production in said conductors of stationary electric waves, of a capacity connection between said wires adapted to lengthen their period of vibration, and a wave-indicating device connected between said wires.

50. In space telegraphy, the combination with parallel conductors, means connected therewith for the production in said conductors of stationary electrical waves, a capacity connection between said wires adjacent the static loop of the waves in said conductors, and a wave-indicating device connecting said conductors adjacent a static loop of the waves therein.

51. In space telegraphy, the combination with an antenna and two parallel conductors which are connected at one end and one with the antenna and the other with the earth or other capacity, and a wave-indicating device connected between said conductors.

52. In space telegraphy, the combination with an antenna and two parallel conductors, one of which is connected with the antenna, of condensers inserted between said parallel wires, and a wave-indicating device in shunt about said condensers.

53. In space telegraphy, the combination with an antenna and two parallel conductors which are connected at one end, one with the antenna and the other with the earth or large capacity, and a wave-indicating device connected between said conductors at a point along the wires substantially corresponding to a loop of the wave with which it is designed to operate.

54. In space telegraphy, the combination with an antenna and two parallel conductors, one of which is connected with the antenna, a lag-producing device operative upon said conductors, and a wave-indicating device connected with such conductors.

55. In space telegraphy, the combination with an antenna and two parallel conductors, one of which is connected with the antenna, of lag-producing devices operative upon said

conductors, means for adjusting said devices, to control the amount of lag produced thereby, and a wave-indicating device connected with said conductors.

56. In space telegraphy, the combination with an antenna and two parallel conductors, one of which is connected with the antenna, of condensers connected with said conductors and having their poles adjustable toward and from each other, and a wave-indicating device connected with said conductors.

57. In space telegraphy, the combination with an antenna, two parallel conductors, one of which is connected with the antenna, of a condenser connected between said conductors substantially at an electrostatic loop of the waves therein, and a wave-indicating device connected between said conductors substantially at a loop of the electrostatic wave therein.

58. In space telegraphy, an antenna, a conductor connected therewith and adapted to the production of stationary waves harmonizing in period with those of the antenna, a wave-indicating device connected with the conductor, and connections with said conductor between the wave-indicating device and the antenna adapted to remove from the conductor such waves as are not in harmony with its designed period.

59. In a sending apparatus for space telegraphy, the combination with a wave-producing device and an antenna, of a conductor connecting the wave-producing device and the antenna and equivalent in length to a multiple of a quarter-wave length, and a second conductor parallel thereto and acting inductively to produce stationary electrical waves.

60. In a sending apparatus for space telegraphy, the combination with a wave-producing device and an antenna, of parallel conductors connecting the wave-producing device and the antenna and equivalent in length to a multiple of a quarter-wave length, and bridges connecting said parallel conductors substantially at nodes of the waves produced therein.

61. In a sending apparatus for space telegraphy, the combination with a wave-producing device and an antenna, of parallel conductors connecting the wave-producing device and the antenna and equivalent in length to a multiple of a quarter-wave length, bridges connecting said parallel conductors substantially at nodes of the waves produced, and ground connections for said bridges.

62. In space telegraphy, the combination with a wave-producing device and a radiating antenna, of a plurality of conductors connecting the wave-producing device and the antenna and the other acting inductively therewith to produce stationary electrical waves.

63. In space telegraphy, the combination with a wave-producing device and a radiat-

ing antenna, of a plurality of parallel conductors each equivalent in length to a multiple of a quarter-wave length, said conductors being adapted to the production of stationary vibrations, one of said conductors connecting the wave-producing device and the antenna

In testimony whereof I have hereunto affixed my signature in the presence of two witnesses

LEE DE FOREST.

Witnesses

H. L. REYNOLDS,  
ADOLPH FUCHS.

PLAINTIFF'S EXHIBIT 203

62

*Circular of the Bureau of Standards*

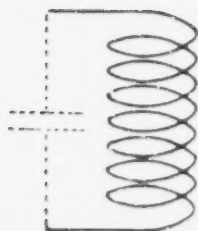


FIG. 45.—Circuit which is equivalent to a coil having distributed capacity.

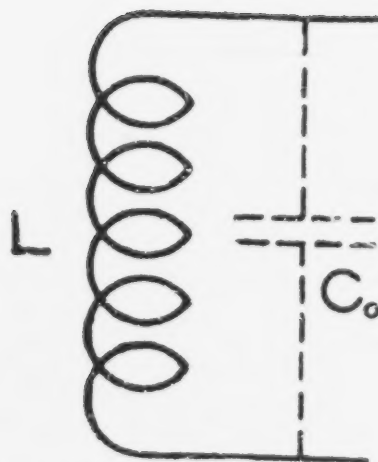
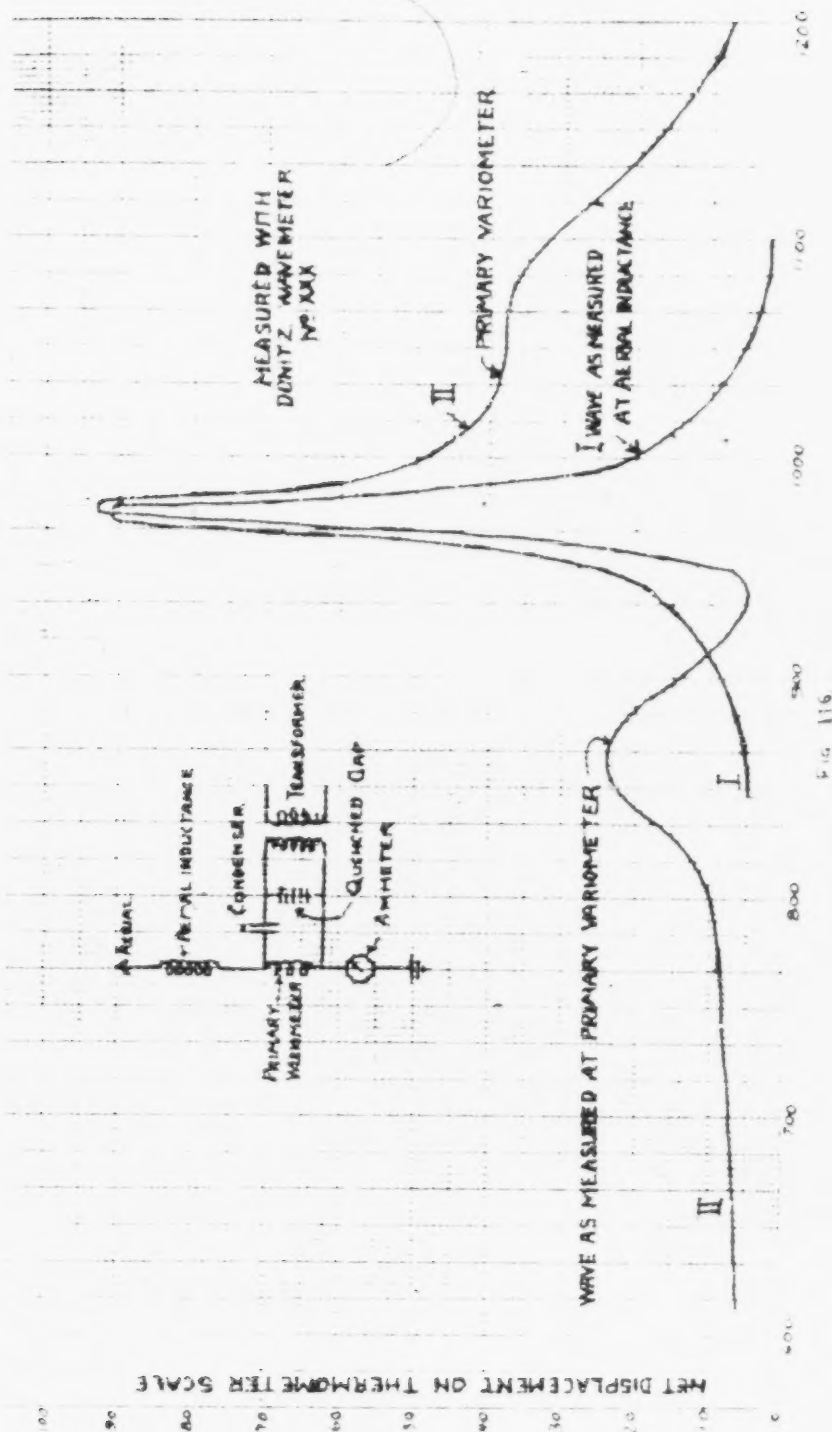


Fig. 218.—Distributed Capacity of Inductance.

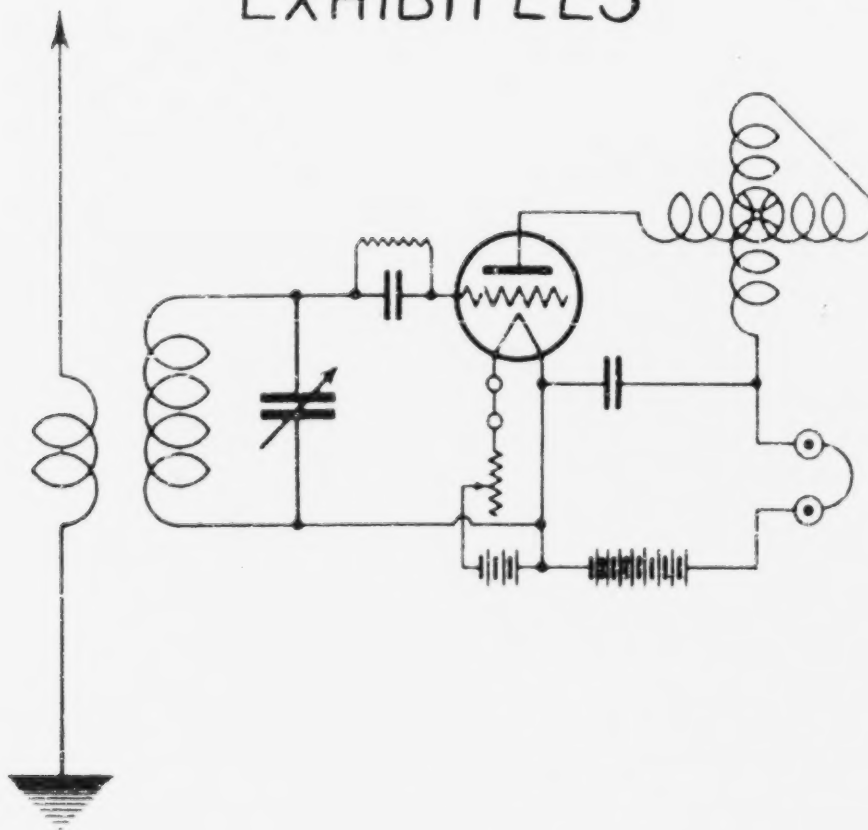
# Claimant's Exhibit No. 211

MANUAL OF WIRELESS TELEGRAPHY



Claimant's Exhibit No. 223

## EXHIBIT 223



Claimant's Exhibit No. 225

# EXHIBIT 225

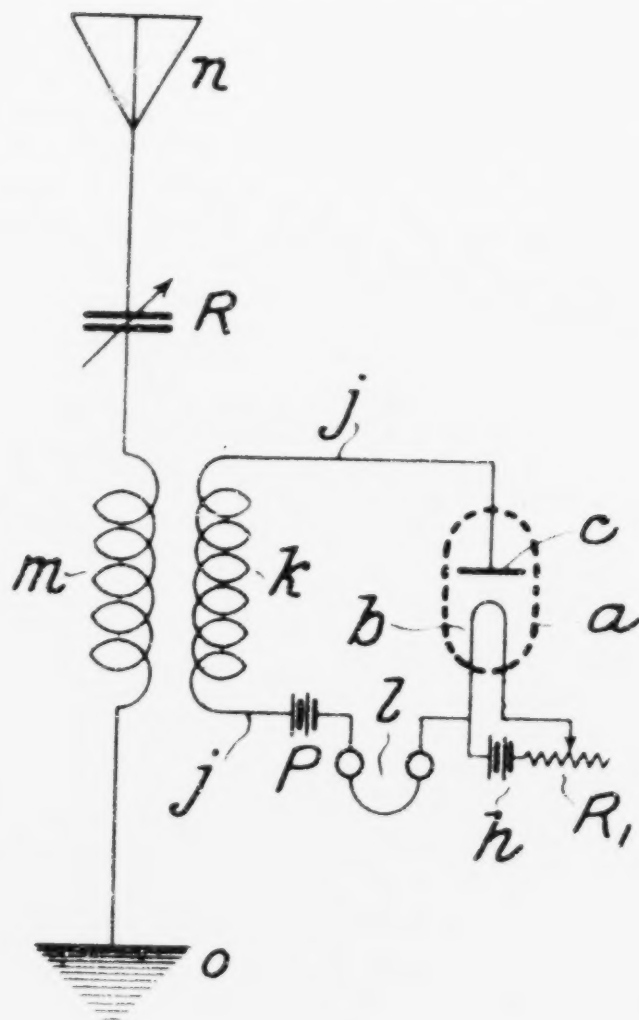
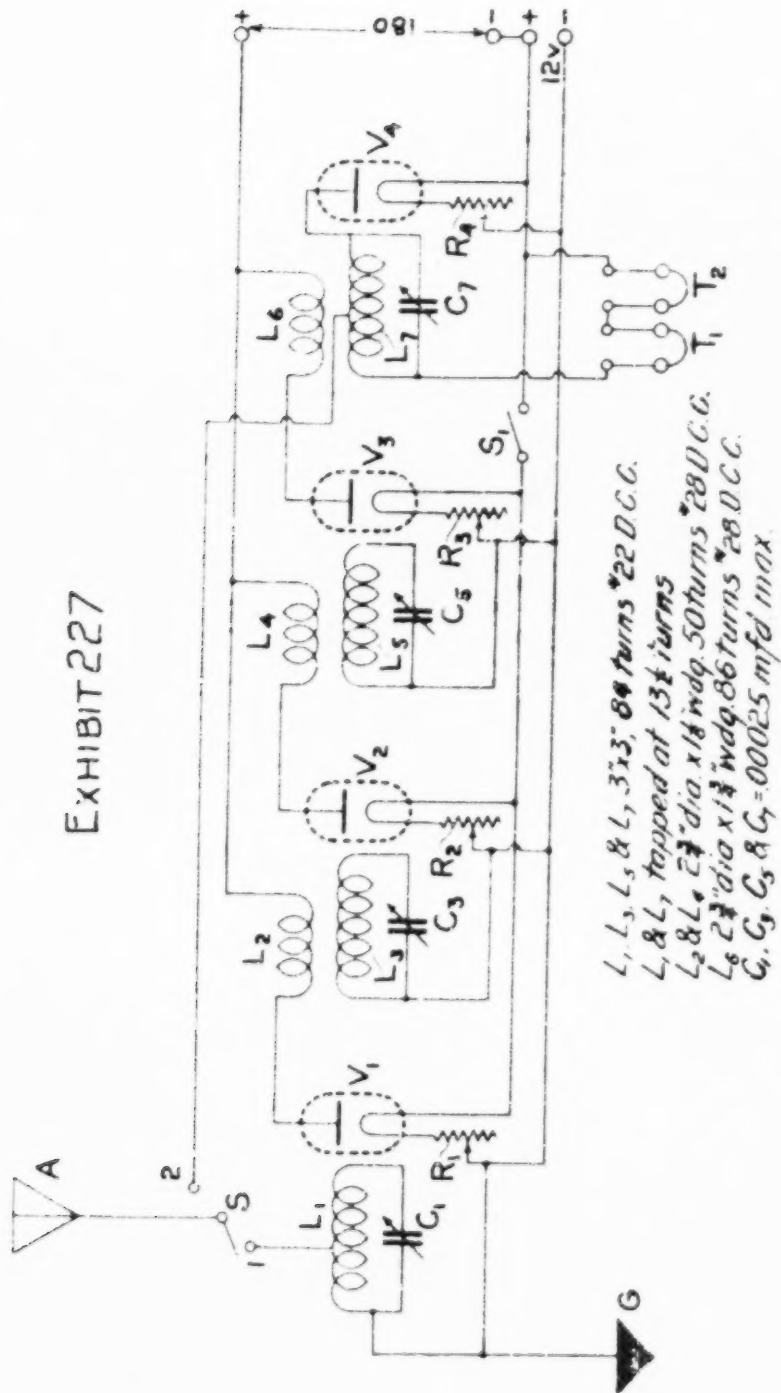
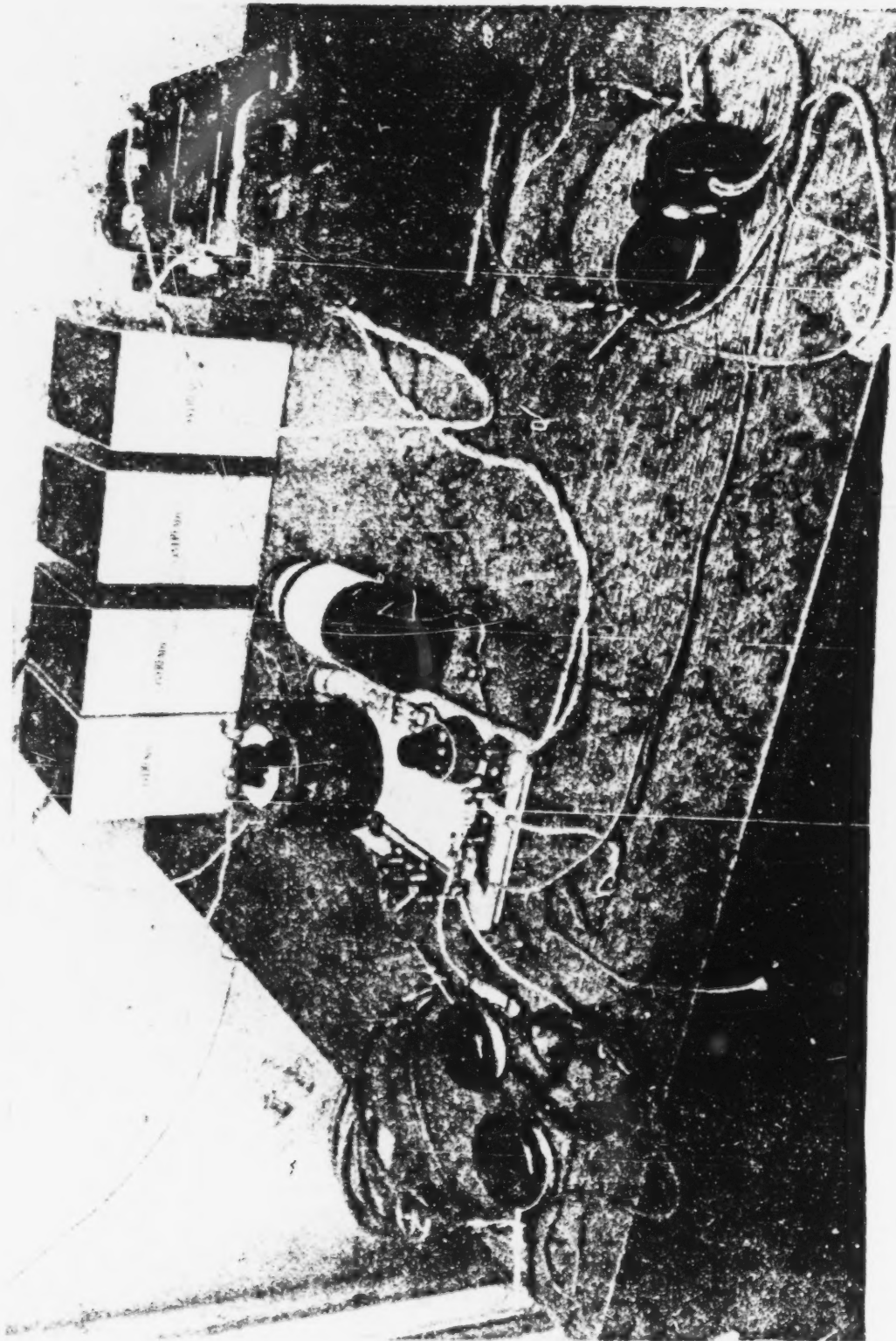


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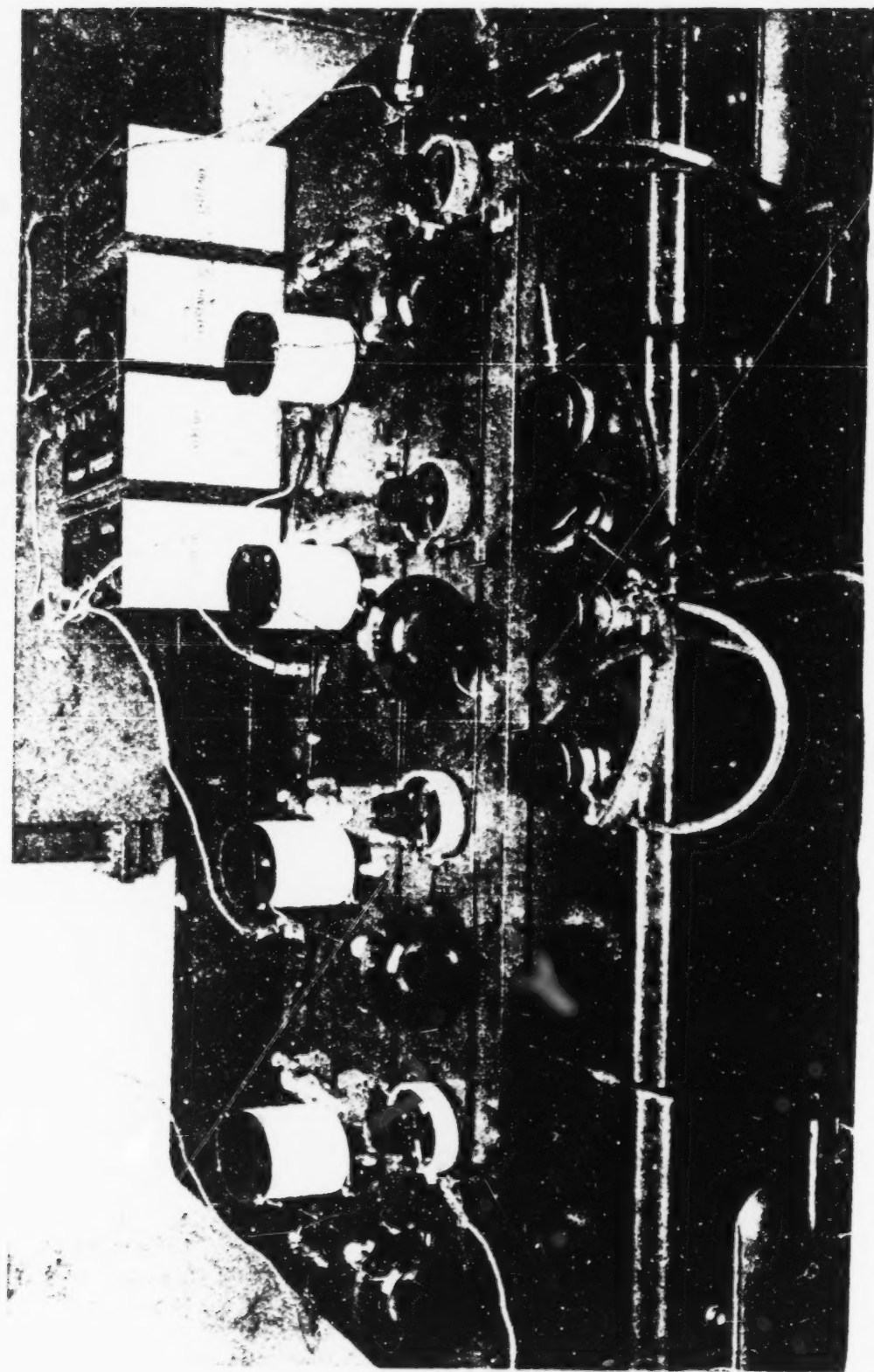
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Claimant's Exhibit No. 228



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Claimant's Exhibit No. 229



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## Operating Features of the Audion

Explanation of its action as an amplifier,  
as a detector of high-frequency oscillations  
and as a "valve." By E. H. Armstrong

ALTHOUGH the audion has been in use for several years as an amplifier and a detector of high-frequency oscillations, the explanations advanced to account for its action do not appear to be satisfactory. With the idea of pointing out some features of action which heretofore do not seem to have been

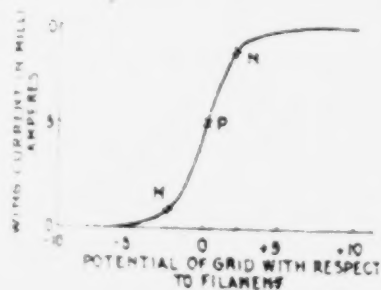


FIG. 1—VARIATION OF WING CURRENT WITH GRID POTENTIAL

approximated the following explanation and oscillograms are given.

The audion is essentially an electron relay; that is, an exhaustion is carried to such a point that the amount of gas present is exceedingly small, and the current between the hot and cold electrodes is entirely thermionic, the absence of gas making impossible the presence of positive ions. The operating characteristic of such a relay is as shown in Fig. 1. This characteristic was obtained in the manner indicated in Fig. 2.

The potential of the grid with respect to the filament was varied in steps between  $-10$  and  $+10$  volts, by means of the potentiometer  $P$ , corresponding readings of grid voltage and wing current being taken in order to plot the curve of Fig. 1. The characteristic shows that starting with the grid and filament at zero potential difference, a negative charge imparted to the grid produces a decrease in the wing current and a positive

with respect to the filament, but only one grid was employed. It was found that, under similar conditions of filament temperature and voltage of the battery  $B_1$ , a considerably smaller current was obtained between the filament and plate on the side in which the grid was inserted. In both measurements the grid was left entirely free of any connection with the rest of the apparatus. Obviously the grid obstructed the flow of the thermionic current. Investigation showed that this was due to the charge accumulating on the grid when exposed to bombardment by the electrons passing from



FIG. 4—TIME VARIATION OF GRID POTENTIAL AND WING CURRENT

the filament to the wing. The electrons pass readily enough into the grid but cannot easily escape from it, and as a consequence of this negative electricity pile-up on the grid. The potential assumed by the grid when exposed to this bombardment may be several volts negative with respect to the negative terminal of the filament, it may be the same as the negative terminal, or it may be positive with respect to the negative terminal, but it will always be negative with respect to the potential of the field in the plane of the grid which would exist if the grid were removed from the bulb. The negative charge on the grid, therefore, impedes the flow of electrons from filament to plate, causing the decrease in the wing current. The placing of a positive charge on the grid from an external source tends to neutralize the negative charge on the grid, thereby permitting an increase in the wing current. The addition of a negative charge to the grid increases the deflection

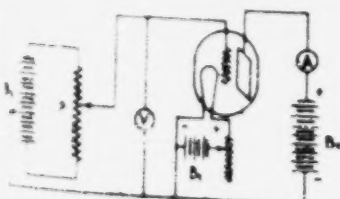


FIG. 2—CONNECTIONS FOR OBSERVING WING CURRENT AND GRID POTENTIAL

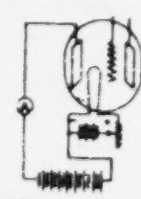


FIG. 3—CONNECTIONS GIVING TWO VALUES OF WING CURRENT

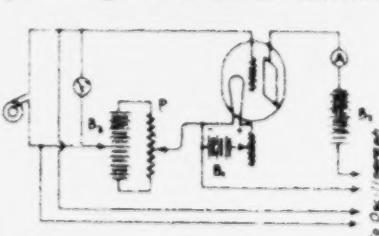
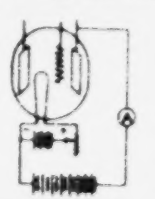


FIG. 5—CONNECTIONS TO OSCILLOGRAPH

charge imparted to the grid produces an increase in the wing current. This is the fundamental action of the audion when used either as an amplifier or a detector. The reason for this action will appear upon examination of the behavior of an audion of the type shown in Fig. 3.

The wings of the audion were placed symmetrically

of the electrons and produces a further decrease in the wing current.

An alternating emf impressed between the grid and the filament causes variations in the wing current in the manner indicated in Fig. 4, the positive alternation producing an increase and the negative alternation a decrease in the wing current. This is the action in-

volved in the audion when it is used as an amplifier.

To substantiate the above and other actions, the writer, working in conjunction with Prof. J. H. Morecroft, of Columbia University, has secured oscillograms which substantiate the idea just presented. Fig. 5

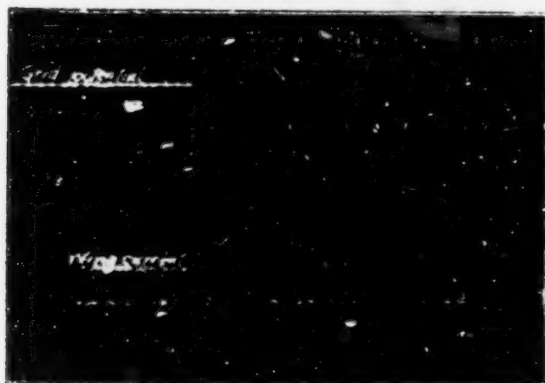


FIG. 6—ACTION OF AUDION AS AN AMPLIFIER

shows the arrangements with which the test was carried out.

The potentiometer *P* was used to adjust the grid to a potential corresponding to point *P* at the center of the operating part of the curve shown in Fig. 1. The audion is capable of handling the greatest amount of

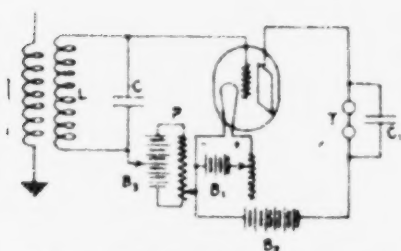


FIG. 7—USE OF AUDION AS AN OSCILLATION DETECTOR

energy as an amplifier when the grid potential is adjusted to this point.

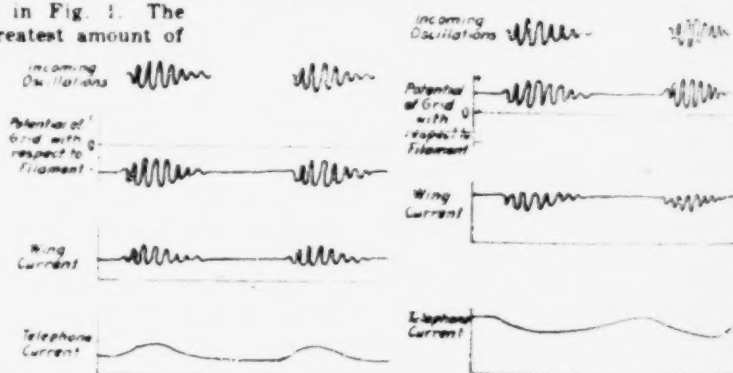
Fig. 6 shows the oscillogram of the action as an amplifier. The result bears out the explanation already given.

The action of the audion as a detector of high-frequency oscillations is quite different from its action as an amplifier. Since the incoming oscillations are of too high a frequency to affect directly the telephone receiver, the audion must be so connected and adjusted that the cumulative effect of a group of oscillations in the grid circuit is translated into a single low-frequency pulse or variation in the telephone current. This may be done in two ways, one depending on the non-linear form of the operating characteristic of the audion and the other depending on the so-called "valve" action between hot and cold electrodes at low pressures.

Fig. 7 shows the connection used for operating in the first-named manner. The potentiometer *P* is employed for the purpose of adjusting the potential of the grid to point *M* on the characteristic curve of Fig. 1. The action is much the same as in one of Professor Fleming's methods of using his valve. A group of high-frequency oscillations impressed on the grid causes corresponding high-frequency variations in the continuous current in the wing circuit, but owing to the fixing of the grid

potential at the lower bend in the curve by adjustment of the potentiometer in the grid circuit, the amplitude of the positive part of the high-frequency current in the wing circuit exceeds the amplitude of the negative part. As the positive half-waves are greater than the negative half-waves, more electricity flows in one direction than the other, and the condenser *C*, through which the high-frequency current in the wing circuit flows, becomes charged, the side connected to the battery *B*, having the positive charge. This charge accumulates in *C* a relatively short time, approximately that of the duration of a wave train. *C* then discharges through the telephones *T*, the rate of this discharge being determined by the constants of the telephones and the condenser. It is probable that this discharge is aperiodic or nearly so. In any case the main part of the discharge through the telephones is in the same direction as the current due to the battery *B*, and constitutes an increase in the current in the telephones. As this action is repeated for each group of oscillations, a series of wave trains causes what might be regarded (in its action on the telephones) as an alternating current in the telephone superposed on the continuous current and having a fundamental frequency equal to the number of wave trains per second. The action is shown diagrammatically in Fig. 8.

If the potential of the grid is adjusted to the upper bend in the curve of Fig. 1, as at point *N*, the fund-



FIGS. 8 AND 9—ACTION OF AUDION AS AN OSCILLATION DETECTOR

mental action will be the same, but the effect of high-frequency oscillations in the grid circuit on the wing current will be reversed. The amplitude of the negative part of the high-frequency oscillations in the wing circuit will exceed the amplitude of the positive part.

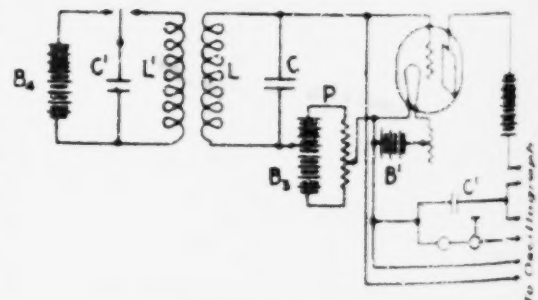


FIG. 10—CONNECTIONS TO OSCILLOGRAPH

the condenser *C*, will become charged, but in the opposite sense, the side connected to the battery *B*, becoming negative. The discharge of the condenser through the telephones will therefore be in the opposite direction to the flow of the continuous current of the wing circuit.

and will constitute a decrease in the telephone current. Diagrammatically the action is as indicated in Fig. 9. Oscillograms bearing on these actions were obtained in the manner indicated in Fig. 10. Oscillations were set up by the discharge of the condenser  $C$  through the

ing wave train sets up oscillations in the closed circuit  $LC$  which are rectified by the "valve" action of the filament and grid, and the rectified current is used to charge the condenser  $C$ . Electrons pass readily enough

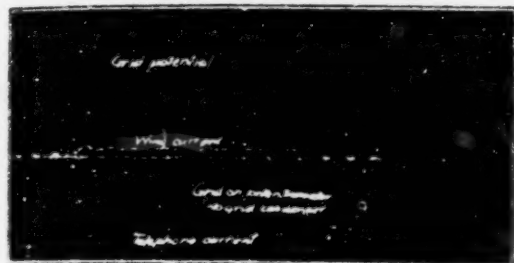


FIG. 11—OSCILLOGRAM OF ACTION AS A DETECTOR

inductance  $L$ , which was coupled with the inductance  $L$  of the tuned grid circuit. To permit the use of an ordinary General Electric oscillograph, an oscillation frequency of about fifty cycles per second and a group frequency of two or three cycles were employed. The action of the audion is the same regardless of frequency, provided that the circuit constants are suitably modified to fit the frequency employed. In this case the oscillation frequency of the circuit  $LC$  was fifty cycles and the circuit  $LC$  was accordingly tuned to the same frequency. The capacity of  $C$  was selected to correspond to the low frequency employed. Figs. 11 and 12 show oscillograms taken as indicated in Fig. 10, with the grid potential adjusted respectively to the lower and upper bends of the operating characteristic.

It will be observed that the telephone current reaches in Fig. 11 its maximum value, and in Fig. 12 its minimum value, when the oscillating current has almost died away. This effect would be shown more plainly with a higher oscillation frequency, but even at the frequency used it is quite evident.

To make use of the "valve" action between hot and cold electrodes for the detection of high-frequency oscillations a connection as shown in Fig. 13 is used.

In this case a condenser  $C$ , is inserted somewhere in the circuit between the grid and filament to prevent the flow of a continuous current between them, and the grid is therefore left free to assume a potential determined by its position with respect to the filament and wing. Usually this will be somewhere near the center

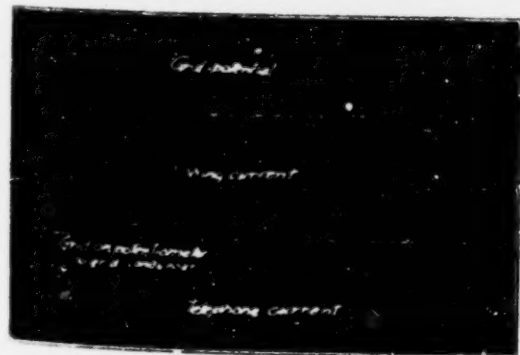


FIG. 12—OSCILLOGRAM OF ACTION AS A DETECTOR

of the operating part of the curve of Fig. 1; that is, near point  $P$ . Now the action for incoming oscillations, as far as the closed oscillating circuit, filament, grid and condenser  $C$ , are concerned, is identical with the rectifying action of the Fleming valve. An incom-

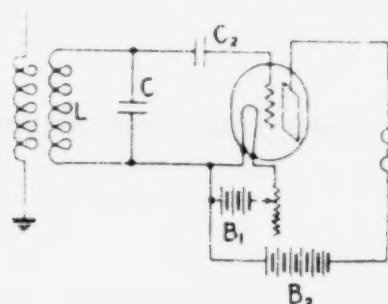


FIG. 13—USE OF AUDION AS A "VALVE"

ing wave train sets up oscillations in the closed circuit  $LC$  which are rectified by the "valve" action of the filament and grid, and the rectified current is used to charge the condenser  $C$ . Electrons pass readily enough

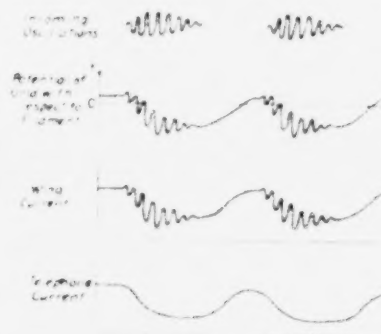


FIG. 14—ACTION OF AUDION AS A "VALVE"

train the charge in  $C$ , gradually leaks off and the wing current returns to its normal value. The charge and discharge of this condenser take place in the manner indicated in Fig. 14.

One group of oscillations produces a single low-frequency variation (decrease) in the telephone current

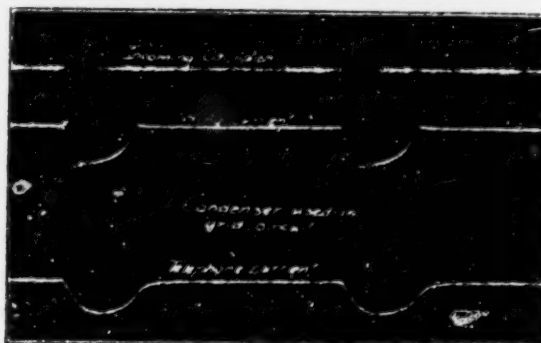


FIG. 15—OSCILLOGRAM OF ACTION AS A "VALVE"

and a series of wave trains produces a corresponding series of low-frequency variations in the telephone current. In Fig. 15 is shown an oscillogram of the behavior of the audion when the "valve" action is employed for the detection of oscillations.

With the means at hand it was impossible to ascertain the variations of the grid potential, as the leak introduced by connecting the oscillograph to the grid would destroy the cumulative action in the grid condenser. The grid potential, however, varies in exactly the same manner as the wing current. It will be seen that the fundamental detecting action is that of a valve, the high-frequency oscillations being rectified between the filament and grid, thereby causing a charge to accumulate on the grid and in the grid condenser. The charged grid then exerts a relay or trigger action on the wing current so that the audion is at once a rectifier and an amplifier. A somewhat similar combination of rectifying and amplifying actions occurs in the arrangement shown in Fig. 7. The action of the audion is being further studied by Prof. Morecroft and the writer in the research laboratory in electro-mechanics, Columbia University, and the results of these investigations will soon be published.

#### High-Potential Voltmeter Based on Corona Pressures

Striving by experiment to determine the relation between the corona current and the increase in air pressure which occurs if direct-current corona takes place in an inclosed space, members of the physics department of the University of Illinois, Urbana, have hopes of being able to construct a high-potential voltmeter based on this pressure phenomenon. Professor Jacob Kunz, in describing some of the experiments before the American Physical Society, stated that the tests covered potentials ranging from 3000 volts to 15,000 volts and that manometer deflections as great as 25 cm had been observed. Professor Kunz emphasized the fact that the pressure noted was not due to heating of the air, for the liquid used in the manometer responded instantly upon the application of potential. Curves plotted between potential and pressure from data obtained thus far approximate very nearly to straight lines.

#### The Electron Theory and Metallic Selenium Crystals

Since the usual free-electron hypothesis does not offer an explanation of (1) the increase of light sensitiveness with pressure, proportional to the conductivity of metallic selenium crystals in the dark, (2) why the change of conductivity by pressure or electrical fields is limited to the region of the crystal under stress, and (3) why the increase of light sensitiveness is limited to the region under pressure and is practically unlimited as to what region of the crystal is illuminated, Prof. F. C. Brown, Iowa State University, Iowa City, has proposed a modified form of the electron theory to satisfy all the fundamental experiments thus far recorded. This new view supposes that a large portion of the conducting electrons in the crystal are ordinarily fixed in the crystal structure in varying degrees of stability. When an electric field is established across the crystal a certain average number of these fixed electrons is rendered unstable or free. The divergence from the usually accepted notion is the conception that these electrons remain free only for a relatively short interval of time. Thus in these crystals the current increases with voltage more rapidly than is required by Ohm's law.

The effect of the increase of pressure is to lessen the degree of the stability, so that the mean interval before the recombination of the electrons is increased. "Obviously," says Professor Brown, "this seems to ex-

plain satisfactorily the increased light sensitiveness with increased pressure, and also the exact proportionality observed. It also explains the limitation of the increase to the region of the crystal under pressure. The transmitted light action observed by Prof. L. E. Sieg and myself is probably a mechanical disturbance propagated in the crystal, and enters into this theory only as the disturbance keeps electrons out of their fixed positions. If it were not for this rapid recombination of the electrons, the change of conductivity by pressure or electrical forces should be noticeable throughout a given crystal structure."

In closing his remarks, which were made before the American Physical Society at Chicago, Professor Brown suggested that a study of the conducting changes very near the region of applied pressure might give some information as to the rate of recombination of the electrons.

#### Valuation in Houston, Tex.

Messrs. James E. Allison & Company, of St. Louis Mo., have submitted a report on the rate case of the Houston (Tex.) Lighting & Power Company Ltd. They represented the company and reported on the capital now invested in the property and entitled to return. In the letter of transmittal they say that they were aware that the report was to be submitted to the consideration of the Mayor and commission of the city of Houston in connection with a contemplated regulation of rates. A report on the property has been made by Messrs. Lyndon & Elrod, representing the Mayor of Houston.

In stating that valuation for rate making is comparatively new, the report says that the Wisconsin commission "is the one which is in great part responsible for the adoption of theoretical depreciation, and is a very curious commentary on the theory of its members put forth in the early part of their work that while nearly all of their cases they figure out the depreciated value, yet when they come actually to assign the amount of capital entitled to return, the effect of depreciation cannot always be traced clearly in their announced result. The commission, while it has not yet admitted the error of applying this theory, has generally raised the figures of its valuations as not to bring its results very seriously in question. There seems to have been what may be called an instinctive recognition of a just amount which has often been assigned in the commission's reports without making it very clear as how it was arrived at.

"Notwithstanding that by such methods of argument at practical justice the Wisconsin commission has preserved itself from bringing about an impossible state of affairs in that State, yet its doctrine, which it does not always follow, has gone forth and has been adopted in many other places without that careful analysis which should have been given it. The consequence is that while Wisconsin has in some quarters gained a reputation for fair treatment of its utilities and may have so far escaped complete stagnation in utility enterprises, other localities which have followed the doctrines of Wisconsin without following its practice are already beginning to feel the effect of a theory of valuation under which private capital will not enter the public service."

An appendix to the report includes papers on the subject of depreciation by Mr. James E. Allison, Prof. Allyn A. Young, Cornell University, Prof. J. Laurence Laughlin, University of Chicago; Prof. W. F. Coptak, Washington University, and Prof. Lewis H. Hoadley, University of Texas.

# Plaintiff's Exhibit 241.

## CHAPTER 10. OSCILLATIONS IN CONDENSER CIRCUITS. 117

in which  $\lambda$  is the frequency,  $e$  is the base of the natural logarithms, and  $I_0$  is the "initial amplitude" when  $t = 0$ .

Fig. 16 shows the decrease in amplitude per cycle for different decrements, while in Table IV the oscillation curves have been drawn out for various decrements.

*d*. It follows from *a* that the deceleration decrement can be determined from the ratio of the energy lost in one cycle to that transferred in the same cycle. Hence, substituting  $I$  for  $I_{\infty}$ , we have

$$d = \frac{\frac{1}{2} R I^2 T}{\frac{1}{2} I^2} = \frac{R}{2L} T = \frac{R}{2\pi L} \quad (14)$$

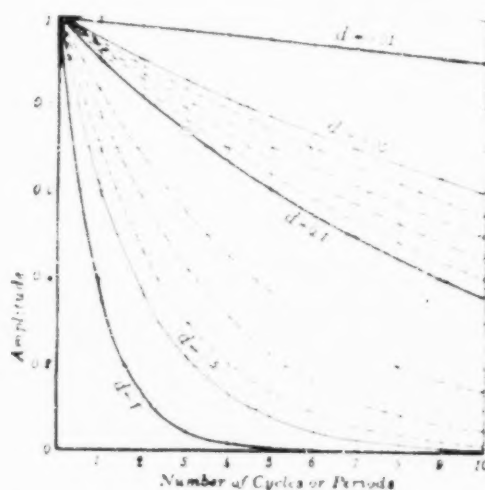


Fig. 16.

or replacing  $T$  by  $2\pi\sqrt{LC}$  (Art. 3a) we have

$$d_c = \pi R \sqrt{\frac{C}{L}}$$

or from the foot-note in Art. 3a

$$d_c = 2\pi^2 \frac{R C}{L \lambda}$$

### 9. Condenser Circuit with Spark Gap. Damping due to Spark.

*a*. The curves  $A_1$  and  $A_2$  of Fig. 17 are the amplitude curves of condenser circuits containing a spark gap (J. ZEISSCKE\*) obtained with the Braghi Tube,  $A_1$  being for a circuit of very low  $R$ ,  $A_2$  for one with higher ohmic resistance. Comparison with Fig. 16 shows a marked difference from the cases in which the damping is due to heat loss only. The amplitude

\* In Fig. 14,  $A_1$  in the upper  $I_0$  in the lower curve.

$\frac{1}{L} = 6000 \times 10^3 = R_{\infty} = C M F = 5020 \times R_{\infty} = C M F$  or  $\frac{R_{\infty}}{\lambda_{\infty}} = 150 \times 10^3$  approximately.

WIRELESS TELEGRAPHY

curve is no longer an exponential curve but approaches a straight line, and so the energy absorbed by the spark exceeds that of the exponential curve. This condition is obtained when the spark gap is made of copper brass, aluminum, silver, etc., while with magnesium the curve tends toward the exponential form.

If the amplitude curve is a straight line the amplitude  $A$  at any time  $t$  is given by

$$A = A_0 \left( 1 - \frac{d}{T} t \right)$$

where  $A_0$  is the initial amplitude and  $d$  is the "linear decrement" which is the decrease in amplitude just as  $L$ , the logarithmic decrement, is for the exponential curves.

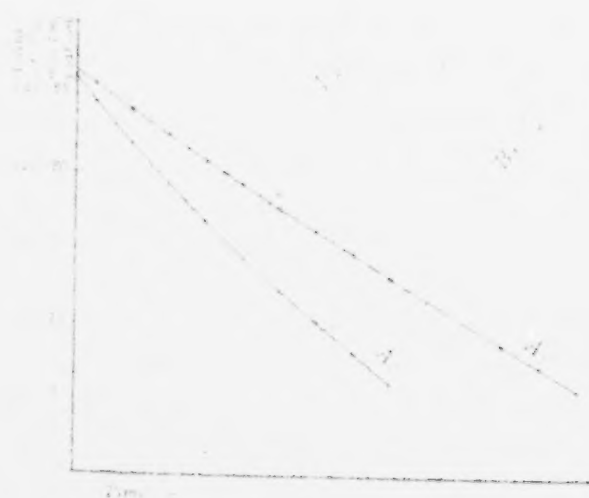


Fig. 17.

If the amplitude differs from the exponential form, this is evidence that the conditions for the absorption of energy in the spark gap are not those for absorption due to ohmic resistance, but are of the type of an electric arc. V. HEDWIGSEN<sup>1</sup>. For this case the energy  $A_0$  absorbed per second in terms of the current is

$$A_0 = nI^2 \quad (1)$$

where  $n$  is a constant for the particular spark gap (1 ohm-sec) which for the present purpose may be taken as

$$n = 1 \quad (2)$$

$$A_0 = I^2$$

Now, if the current across the gap is  $I$  it follows from (2) that the gap

# Claimant's Exhibit No. 242

## WIRELESS TELEGRAPHY

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The conditions may be such, however, that the spark gap, during the time in which the amplitude in the primary circuit is very small, becomes

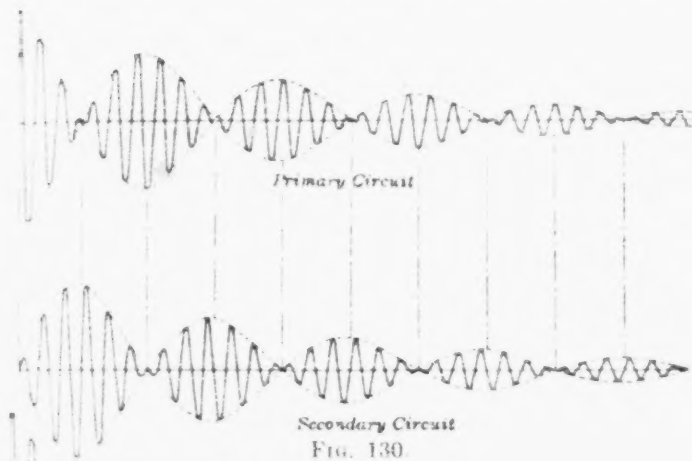


FIG. 130.

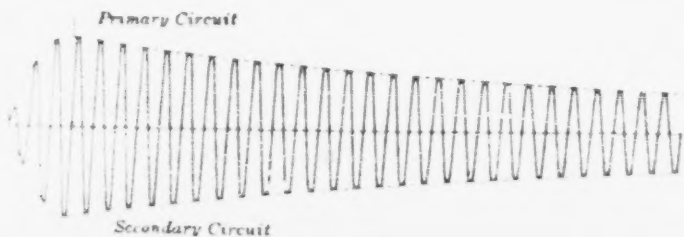


FIG. 131.

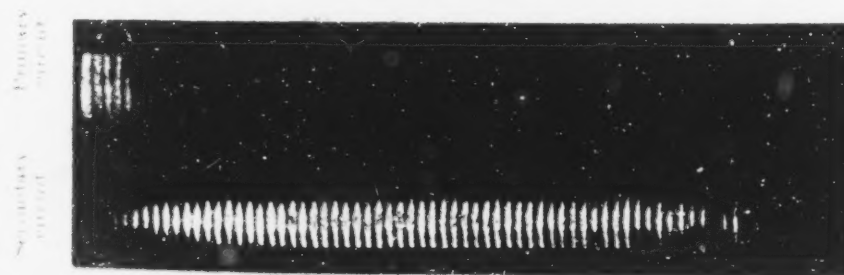
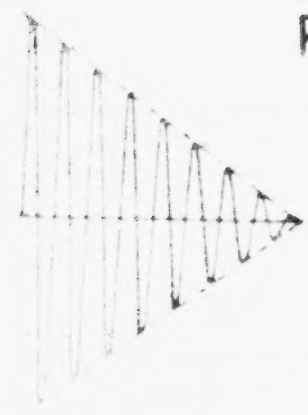


FIG. 132.

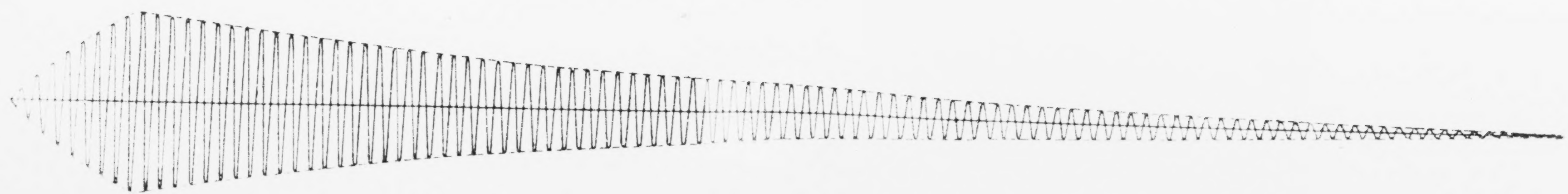
so decreased, that the EMF induced by the secondary is no longer sufficient to start or "ignite" a spark discharge across the gap. As a result the spark gap remains quenched - whence the terms "quenching

# WEAGANT SKETCH \*1

PRIMARY



SECONDARY



to ensure that the primary oscillatory and the antenna circuits have identical time periods. For this it is necessary that the  $L_1C_1$  value of one circuit equal the  $L_2C_2$  value of the other. This does not mean that  $L_1$  must equal  $L_2$  and  $C_1$  equal  $C_2$ , but it does mean that the product of  $L_1$  and  $C_1$  expressed in henries and farads, or convenient equivalents, must equal the product of  $L_2$  and  $C_2$  expressed in the same units.

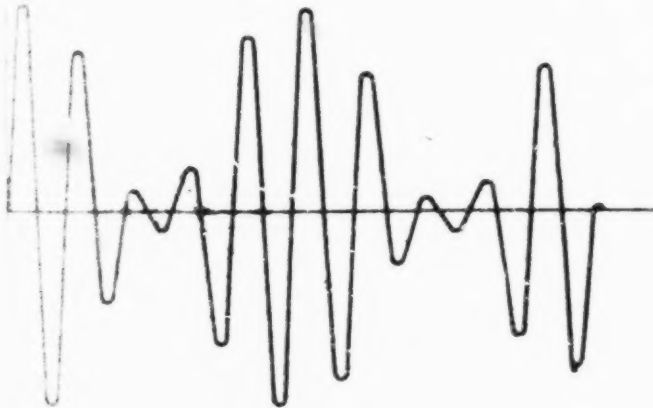


FIG. 274.—Oscillations, Primary Oscillatory Circuit.

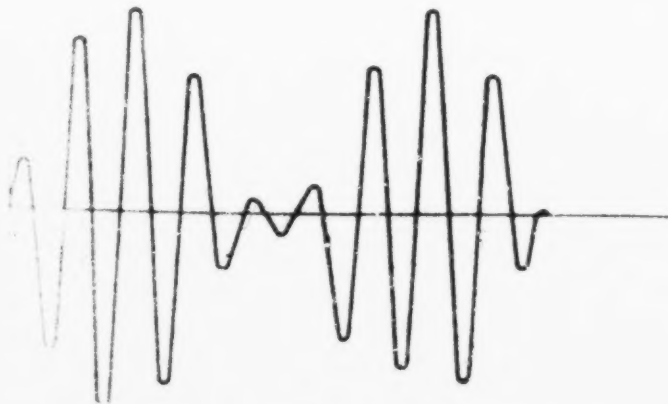


FIG. 275.—Oscillations, Secondary Oscillatory Circuit.

Figs. 274 and 275 indicate the absence of any further interaction between the two circuits, once the transfer of energy has taken place from the primary oscillatory to the antenna circuit. There is, however, a possibility for the antenna circuit to return energy to the primary

It constitutes a very small percentage of the total energy of the antenna in the neighborhood of one to two per cent. coupling. A most important feature in the operation of all spark gaps is the coupling. It may be inductive figure 270, or direct figure 271. The action is largely the same in either case being through the antenna itself, as previously explained. A greater flexibility is possible in the inductive than in the direct arrangement, which has resulted in its use for Navy type transmitters.

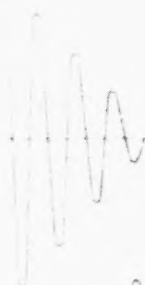


FIG. 272—Oscillations, Primary Oscillatory Circuit.

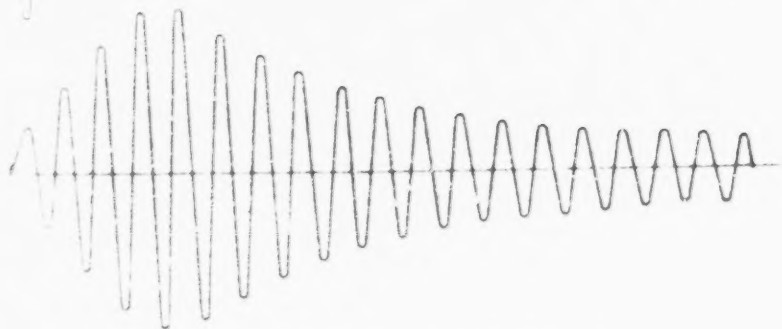
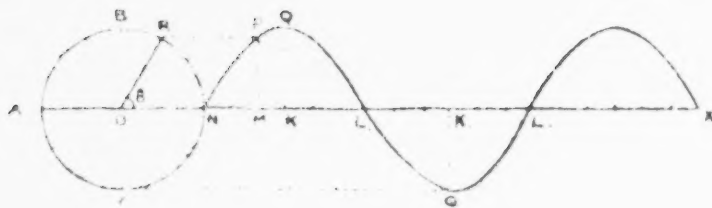


FIG. 273—Oscillations, Secondary Oscillatory Circuit.

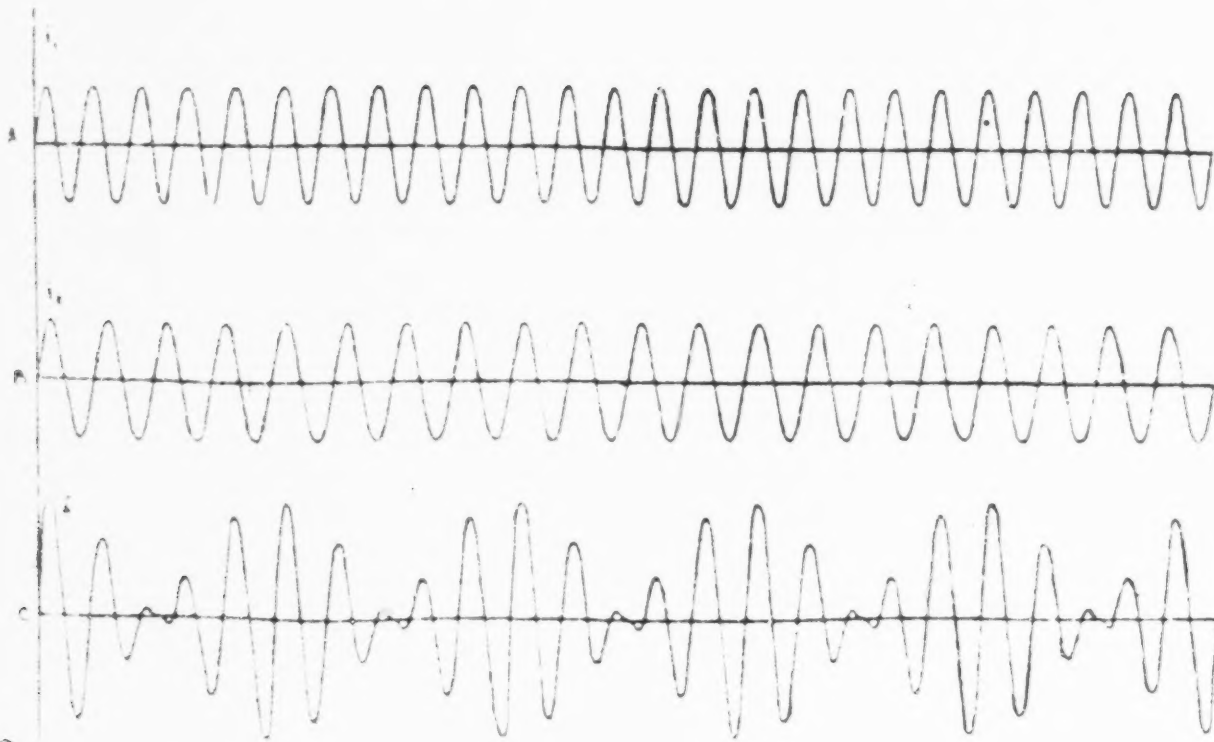
If the characteristics of the primary oscillatory circuit were such that a single discharge took place through the gap from the positive to the negative side of the condenser, there would be imparted excitation to the frequency of the secondary oscillatory circuit would be independent of the constants of the primary oscillatory circuit. The problem would be to secure the greatest possible energy transfer from this current pulse to use to build up radiation, and the coupling would be as close as possible. After each such energy transfer, the energy resulting in the antenna current would flow in the period determined by the antenna  $L/C$  value until reduced to zero by the various losses.

This would be the ideal way, but the actual equipment used permits a series of surges through the gap as indicated figure 272. The resulting secondary oscillations are shown figure 273. If the time periods of the two circuits are the same under these conditions, the coupling is at a maximum, and the energy transfer is at a maximum.

Claimant's Exhibit No. 246



Weagant Sketch No 2



Experiment On Impulse Excitation

By John H. Morecroft

Assistant Professor in Electrical Engineering, Columbia  
University, New York City

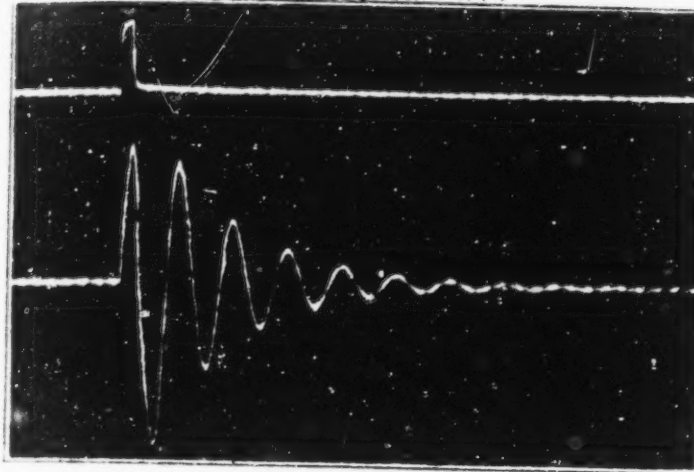


FIGURE 2

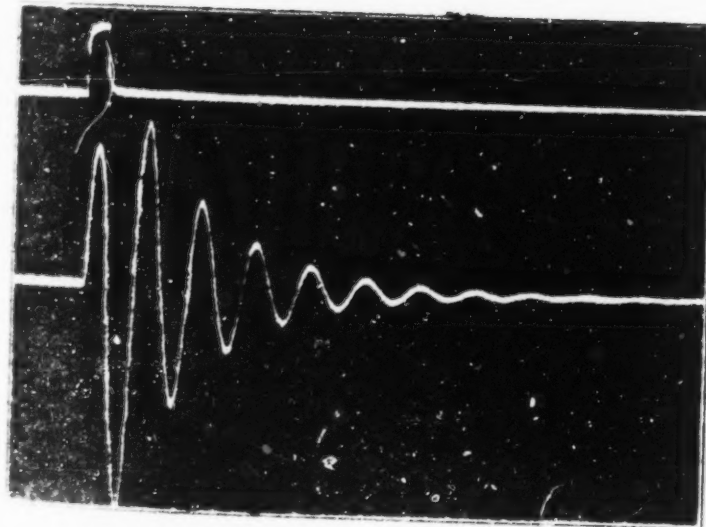


FIGURE 3

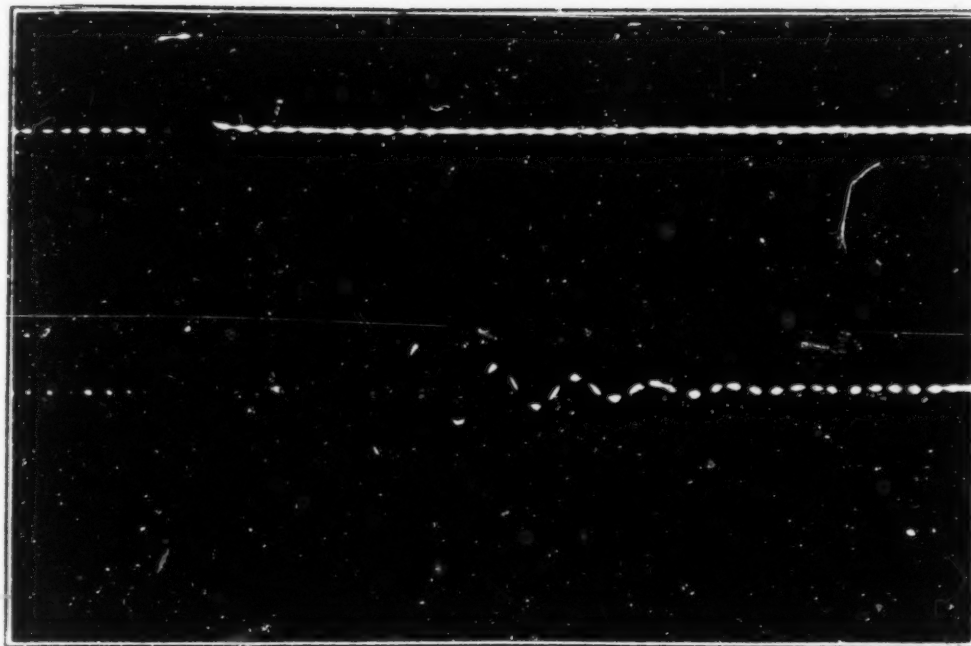


FIGURE 4

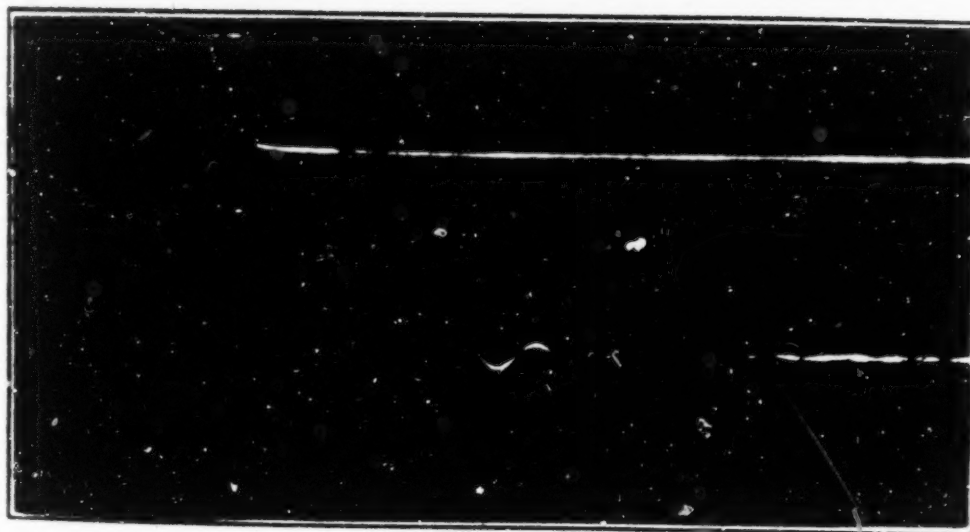


FIGURE 5

2671-2672

Pat. No. 707,975, dated August 10, 1904.

## UNITED STATES PATENT OFFICE.

JOHN STONE STONE, OF CAMBRIDGE, MASSACHUSETTS, ASSIGNOR TO  
WILLIAM W. SWAN, TRUSTEE, OF BROOKLINE, MASSACHUSETTS.

## SPACE TELEGRAPHY.

SPECIFICATION forming part of Letters Patent No. 707,975, dated August 10, 1904.

Application filed November 24, 1902. Serial No. 162,441. No model.

*Be it known that I, JOHN STONE STONE,**a citizen of the United States, and a resident of Cambridge, in the county of Middlesex and State of Massachusetts, have invented a certain new and useful Improvement in Space Telegraphy, of which the following is a specification.*

My invention relates to the art of transmitting intelligence from one station to another by means of electromagnetic waves without the use of wires to guide the waves to their destination; and it relates more particularly to the system of such transmission in which the electromagnetic waves are developed by producing electric vibrations in an elevated conductor, preferably vertically elevated.

In my Letters Patent Nos. 714,756 and 714,831, granted December 2, 1902, I have described a system of selective space telegraphy in which a sonorous or persistently oscillating current is associated with an elevated transmitting conductor for developing in said conductor forced simple harmonic electrical oscillations. The forced simple harmonic electrical oscillations thus developed in the elevated conductor cause the radiation of simple harmonic electromagnetic waves, which, to distinguish them from waves guided to their destination by wires, I have termed "free or unguided electromagnetic waves," although the earth, water, or other natural media over which they pass exerts a guiding influence upon them. In said Letters Patent I have also described a receiving system consisting of a resonant circuit attuned to the frequency of the transmitted waves and associated with an elevated receiving-conductor. I have further described means whereby the system consisting of a complex of circuits is reduced to the equivalent of a system the circuits of which are the equivalent of circuits having a single degree of freedom, said means broadly consisting of an auxiliary inductance for counterbalancing the effect of the mutual inductance between the sonorous circuit and the elevated transmitting-conductor or between the resonant circuit and the elevated receiving-conductor, said inductance being supplied by auxil-

iary coils or by the windings of the coil which associates the sonorous circuit with the elevated conductor.

In the drawing which accompanies and forms a part hereof, the figure represents in diagram a transmitting system embodying my invention.

In the figure, V is an elevated conductor connected to earth at E. V I E is an elevated conductor system. M M' are transformers. L L' are respectively the primary and secondary windings of the transformer M. C C' are condensers. L is an inductance. S is a spark-gap. A is an alternating current generator or other source of periodically-varying electromotive force. K is a key.

For the construction of parts and the operation thereof reference may be had to my hereinbefore-mentioned Letters Patent.

It has long been known that in spark-producing devices—such as static machines, Ruhmkorff coils, &c.—the spark is much larger or "fatter" than it is when it has more energy if a condenser be connected across the terminals of a spark-gap. Such use of a condenser in wireless-telegraph transmitting apparatus has been described by Dr. Martin Tietz in the *Elektrotechnische Zeitschrift*, Vol. 19, No. 33, August 18, 1898, page 562, and a condenser for this purpose has been shown in Patents Nos. 706,735 and 706,736, dated August 12, 1902, and in Patent No. 711,130, dated October 14, 1902.

I have found it advantageous to connect across terminals of the spark-gap S of the sonorous circuit S C L L' a large condenser C C' for the purpose of increasing the size of the spark and for increasing the energy of the disruptive discharge of the condenser C across this gap and also to form a path of low impedance to the electrical oscillations resulting from said disruptive discharge of the condenser C. As I have explained in my Letters Patent hereinbefore referred to, the condenser C in the oscillating circuit S C L L' should be devoid of dielectric loss, so that the oscillations developed in said circuit are to be a purely simple harmonic oscillation, and for this purpose the condenser C may

may be supplied with a dielectric material. Then, as the condenser C, being of great capacity connected to the condenser C', will materially influence the form of the vibrations developed in said circuit, and therefore the dielectric of said condenser C' must be of any substance of high specific inductive capacity and great dielectric strength. This condenser has a capacity great as compared to the capacity of the condenser C, and as the capacity of the condenser C' depends upon the energy desired to be radiated and upon the distance to be traversed I cannot lay down any specific rule as to the actual value of the capacity of condenser C'. The size and length of the conductors connecting the condenser C' with the spark-gap are quite immaterial, and they may have either an appreciable inductance or a negligible inductance without affecting the simple harmonic form of the oscillations developed in the circuit S C L L'. However, it is preferred that the resistance and inductance of these leads be made negligibly small in order to reduce to a minimum the impedance of the shunt around the spark-gap. It will be obvious that the condenser C' is practically short-circuited by the discharge of condenser C' across the spark-gap S, so that condenser C' and the circuit in which it is placed are practically cut out of action after its first discharge so long as the spark lasts. No harmonic whatever, therefore, can be detected when said condenser C' is employed, the form of the radiated wave being practically simple harmonic.

Wherever throughout this specification and its claims I have used the words "simple harmonic waves" I desire to be understood as meaning waves which are as close an approximation as possible to the perfect simple harmonic form; and I herein point out that the discussion of the departure of the waves from such perfect simple harmonic form found in lines 19 to 25 on page 19 of my Letters Patent No. 714,841 is applicable to this case and is hereby made a part hereof, with reference to which my claims are to be construed.

In my Letters Patent No. 714,156 and No. 714,841 I have described and claimed, broadly, a method and apparatus for developing simple harmonic electromagnetic signal waves of a predetermined frequency by producing forced simple harmonic vibrations in an elevated conductor. Certain elevated-conductor systems have a pronounced fundamental rate of vibration, and, as has long been known, if a simple harmonic force be impressed upon such a system the resulting forced vibrations will be most energetic when the period of the force is the same as the period of this fundamental. Under these circumstances its radiation is also more energetic.

In my recent patents I have shown how a simple harmonic force may be impressed upon an elevated conductor system without main-

taining the fundamental of the said elevated conductor system, so that the resulting forced vibrations therein if of the same period as the fundamental as the elevated conductor system may have a maximum of amplitude.

A sharp line of demarcation is to be drawn between the system herein described and such systems as that described, for example, in British Patent No. 71,777, series of 1900. In the system herein described the frequency of the radiated waves is determined solely by the capacity and inductance of the sonorous circuit, which determining the frequency of the electrical oscillations developed in said circuit and by it forced in the elevated conductor, necessarily determining the frequency of the waves radiated by said elevated conductor, the length or other geometric constants of said elevated conductor or its fundamental or its natural periods having no effect in determining the frequency of the radiated waves. In the system described in said British patent and elsewhere, as, for example, in the *Journal of the Society of Arts*, Vol. LI, page 722, in connection with Fig. 14, the frequency of the radiated electromagnetic waves is determined not solely by the capacity and inductance of the sonorous circuit associated with the elevated conductor independently of the capacity and inductance of the latter, but by the capacity and inductance of the elevated conductor taken in conjunction with the capacity and inductance of the associated sonorous circuit and the mutual inductance and capacity of the two circuits. In these systems, which are systems of at least two degrees of freedom, as explained in my prior Letters Patent, any change in the length or other geometric constants of the elevated conductor whereby the capacity and inductance of said conductor is altered will produce a change in the frequency of the radiated waves, and therefore it cannot be said that electrical oscillations in the elevated conductor are forced oscillations of a frequency determined by the electromagnetic constants of the sonorous circuit and irrespective of the constants of the elevated conductor. On the contrary, the system described herein is the equivalent of a system of a single degree of freedom and radiates simple harmonic or substantially simple harmonic electromagnetic waves of a predetermined definite frequency, which frequency is determined entirely by the capacity and inductance of the sonorous circuit and is therefore practically independent of the electromagnetic constants of the elevated conductor. Whereas, as the system described in said British Patent depends for its operativeness upon the correspondence between the fundamental of the elevated conductor with the period of the associated sonorous circuit, the system herein described is merely made more efficient by inducing forced vibrations in the elevated

ductor of the period of the fundamental of said elevated-conductor. The effect may be roughly compared to a stretched cord in a viscous medium vibrated by means of a tuning-fork. Forced vibrations are thereby developed in the stretched cord which are of frequency corresponding with that of the tuning-fork irrespective of the fundamental or natural periods of the cord; but if the fundamental of the cord which corresponds in this analogy to the elevated-conductor system described herein corresponds with the period of the tuning fork which corresponds in this analogy to the sonorous circuit associated with the elevated conductor it will be found that the amplitude of the vibrations executed by the cord are greater, other things being equal, than they would be without such correspondence in period.

I claim

1. In a system for developing free or unguided simple harmonic electromagnetic signal waves of a definite frequency, an elevated-conductor system the fundamental of which has a period equal to the period of the waves to be transmitted, and means for developing the reinforced simple harmonic electric vibrations of corresponding frequency.

2. In a system of space telegraphy, an elevated conductor, a sonorous circuit, associated therewith and containing a condenser, and a condenser of capacity large as compared with the capacity of the condenser in said sonorous circuit, connected across the terminals of a spark-gap in said sonorous circuit.

3. In a system of space telegraphy, a sonorous circuit adapted to develop electric vibrations of a definite frequency, and elevated-conductor system associated therewith, the fundamental period of which is the same as the period of said sonorous circuit, and means for swamping the effect of the mutual inductance between said sonorous circuit and the elevated-conductor system.

4. In a system of space telegraphy, an elevated conductor, a sonorous circuit associated therewith and a condenser connected across the terminals of a spark-gap in said sonorous circuit.

5. In a system for developing free or unguided simple harmonic electromagnetic signal waves of a definite frequency, an elevated-conductor system and a sonorous circuit associated therewith and adapted to develop simple harmonic electric vibrations corresponding in period with the fundamental period of said elevated-conductor system.

6. In a system of space telegraphy, a transmitting system comprising a persistently-oscillating circuit, a good radiating-circuit, the fundamental period of which is equal to the period of said persistently oscillating circuit, and means whereby said transmitting system is reduced to the equivalent of a system of a single degree of freedom.

7. In a system of space telegraphy, a transmitting system comprising a persistently oscillating circuit, a good radiating-circuit, attuned as to its fundamental to the period of said persistently oscillating circuit, and an auxiliary inductance for swamping the effect of the mutual inductance between said circuits.

8. As a means for developing electrical oscillations, a sonorous circuit containing a spark-gap and a condenser of large capacity connected across the terminals of said spark-gap by conductors of low impedance.

9. In a system of space telegraphy, an elevated conductor, a sonorous circuit, containing a spark-gap, associated therewith and a condenser connected across the terminals of said spark-gap by conductors of low impedance.

10. In a system of space telegraphy, an elevated conductor, a sonorous circuit, containing a spark-gap, associated therewith and a circuit consisting of large capacity and low resistance for affording a path of low impedance to the electrical oscillations developed in said sonorous circuit, connected across the terminals of said spark-gap.

11. In a system of space telegraphy, a transmitting system comprising a persistently-oscillating circuit containing the primary of a step-up transformer, a good radiating-circuit containing the secondary of said transformer, the fundamental period of said radiating-circuit being equal to the period of the persistently oscillating circuit, and means whereby said transmitting system is reduced to the equivalent of a system each of whose circuits has a single degree of freedom.

12. In a system of space telegraphy, a sonorous circuit adapted to develop electrical vibrations of a definite frequency, an elevated-conductor system associated therewith by means of a step-up transformer, the fundamental of the elevated-conductor system being equal to the period of the persistently-oscillating circuit, and means for swamping the effect of the mutual inductance between said sonorous circuit and said elevated-conductor system.

13. In a system for developing free or unguided, simple harmonic, electromagnetic signal waves of definite frequency, an elevated-conductor system the fundamental of which has a period equal to the period of the waves to be transmitted, means for developing simple harmonic electrical oscillations of corresponding frequency and means for impressing said electrical oscillations on said elevated-conductor system at increased potential.

14. In a system of space telegraphy, an elevated conductor, the fundamental of which has a period equal to the period of the waves to be transmitted, a sonorous circuit associated with said elevated conductor and adapted to develop electrical oscillations of corre-

...period and a condenser or other capacity connected across the terminals of the spark-gap of said sonorous circuit.

15. In a system of space telegraphy, a persistently-oscillating circuit, and a good radiating-circuit, attuned as to its fundamental to the period of said persistently-oscillating circuit, in combination with means for increasing the amplitude of the electrical oscillations developed in said persistently-oscillating circuit.

16. In a system of space telegraphy, a persistently-oscillating circuit containing a spark-gap, a good radiating-circuit, attuned as to its fundamental to the period of said persistently-oscillating circuit, and a condenser connected across the terminals of said spark-gap.

17. In a system of space telegraphy, a sonorous circuit, a good radiating-circuit, attuned as to its fundamental to the period of said sonorous circuit, and means for impressing the oscillations created in said sonorous circuit upon said good radiating-circuit at increased potential, in combination with means for increasing the persistency of the oscillations developed in said sonorous circuit.

In testimony whereof I have hereunto subscribed my name this 26th day of November, 1903.

JOHN STONE STONE

Witnesses:

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# PLAINTIFF'S EXHIBIT 258

3093

No. 823,402

PATENTED JUNE 12, 1906

L. DE FOREST.

STATIC VALVE FOR WIRELESS TELEGRAPH SYSTEMS.

APPLICATION FILED DEC 9 1905

2 SHEETS-SHEET 1

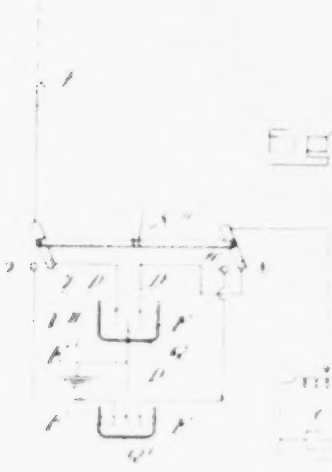
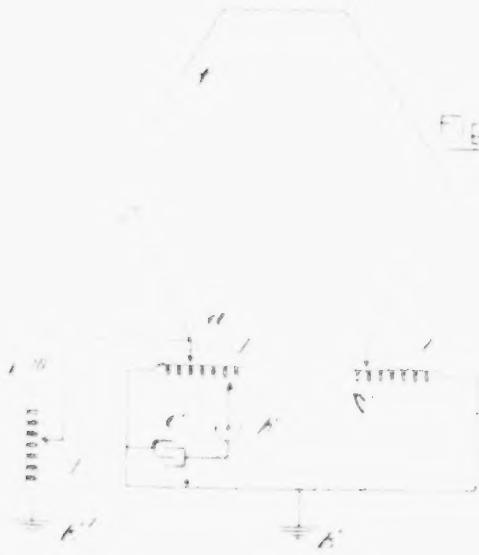


Fig. 1



Fig. 3

Fig. 2



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*John T. ...*

INVENTOR:

*L. de Forest*  
*by Joseph ...*  
*his attorney*

No. 823,402

PATENTED JUNE 12, 1906

L. DE FOREST.

STATIC VALVE FOR WIRELESS TELEGRAPH SYSTEMS.

APPLICATION FILED DEC 8 1904

SHEET 2



FIG. 4

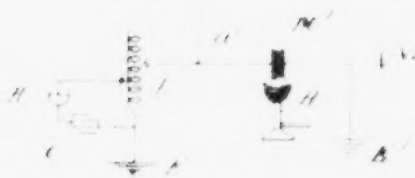


FIG. 5

WITNESSES

*Le Forest*

*Le Forest*

*Le Forest*

*Le Forest*

*Le Forest*

# UNITED STATES PATENT OFFICE.

LEE DE FOREST, OF NEW YORK, N. Y.

## STATIC VALVE FOR WIRELESS-TELEGRAPH SYSTEMS.

No. 823,402

Specification of Letters Patent.

Patented June 12, 1906.

Application filed December 3, 1905. Serial No. 291,067.

*To all whom it may concern:*

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful Improvement in Static Valves for Wireless-Telegraph Systems, of which the following is a specification.

My invention relates to wireless-telegraph receiving systems, and more especially to apparatus and circuit arrangements whereby atmospheric electricity or static disturbances may be minimized or eliminated.

It is well known that the receiving antennae of commercial wireless-telegraph systems often become charged with static electricity by such natural causes as the passage of charged clouds in the vicinity of the antennae, lightning discharges which may be even far distant from the receiving-station, the impingement upon the antennae of winds, especially hot winds, laden with ionized air, &c. Very often such static charges so accumulated by the antennae seriously interfere with the reception of signals transmitted by electromagnetic waves from distant stations, and sometimes, especially in tropical and semitropical climates, these static effects become so pronounced as to entirely prevent the reception of such signals.

The object of the present invention is to provide means for preventing by static valves or leaks any deleterious effect on the reception of signals by static or other natural or artificial electrical forces.

My invention may best be understood by having reference to the drawings which accompany and form a part of this specification and which conventionally represent various forms of static valves or leaks which I have found efficient for carrying out the hereinafore-stated objects, although it is to be understood that I do not limit myself to the specific embodiments of my invention shown in said drawings, inasmuch as many other embodiments thereof may be devised by those skilled in the art without departing from the spirit of my invention.

In the drawings, Figure 1 represents a wireless-telegraph receiving system provided with two forms of static valve or leak. Fig. 2 represents a wireless-telegraph receiving system provided with an electrolytic static valve or leak. Fig. 3 represents a wireless-telegraph receiving system in which an iron spiral is employed as a static leak. Fig. 4

represents a wireless-telegraph receiving system in which a flame is used as a static valve or leak. Fig. 4<sup>a</sup> shows a modification of the device illustrated in Fig. 4, and Fig. 5 represents a wireless-telegraph receiving system in which heated mineral wool or the like is employed as a static leak.

For the purpose of more fully disclosing the present invention I have shown in Fig. 1 two embodiments of the same applied to a receiving system of my invention which comprises a loop antenna, although, as shown in Figs. 2, 4, and 5, the present invention is not limited to any particular kind of receiving system, being capable of application to any type of receiving system.

In Fig. 1, A is a loop antenna, the two sides of which are adjustably connected to the inductances L L', which are connected to earth at E. Across any desired portion of the inductance L the tuned receiving-circuit C R L, including the variable condenser C and responder or oscillation-detector R, is adjustably connected, and by means of the adjustable contact *m* and said variable condenser C the natural period of said tuned receiving-circuit is made equal to that of the loop antenna while by means of the adjustable contacts *n* and *o* the natural period of said loop antenna is made equal to that of the electromagnetic waves to be received. Across the terminals of the responder R is connected the local receiving-circuit, including the telephone T and any desired portion of the potentiometer resistance P, which regulates the potential of the battery B to be impressed upon the responder. A static leak V or V' is connected between the earth E and any suitable point *a* or *b* of the antenna located between the top of the antenna and the adjustable contacts *n* or *o*, and preferably near said adjustable contacts. One static leak only may be employed with a loop antenna, as shown in Fig. 3, and if two are used they may be of the same or of different types. If the receiving system is provided with an open antenna, only one static leak is used, as shown in Figs. 2, 4, and 5.

A variety of devices may be used as static leaks, and I shall now specifically describe the six devices V, V', V'', V''', V'', and V''', shown in the drawings, although it is to be understood that many other devices may be employed.

V is a static valve or leak consisting of an electrolytic cell comprising an electrode F,

which may form a cup of aluminum, tantalum, iron, or other suitable metal an electrode D of carbon, platinum, or other suitable material and an electrolyte cooperating with said electrodes and consisting of ammonium phosphate, caustic soda or potash, or any other suitable chemical solution. A cell so constructed has the well known property of permitting electric currents of given polarity to pass through it in one direction, for example from the carbon electrode to the aluminum electrode, more readily than in the opposite direction. In short, such a cell is an electric valve or asymmetric resistance.

The reversing switch S cooperates with the contacts 1 and 3, which are connected to the electrode D, and the contact 2, which is connected with the cup E, and enables the operator to connect either the electrode D to the antenna and the electrode E to earth or the electrode D to earth. For the purpose of describing the operation of the cell V it will be assumed that the electrode D, which is connected to the antenna in the position of the switch shown in Fig. 1, is carbon and that the electrode E, which is connected to earth in said position of the switch is aluminum. With a cell so constructed and so connected a positive charge of electricity developed in the antenna will readily pass through the cell to earth and will therefore be prevented from affecting the responder R, but a negative charge of electricity developed in the antenna will not pass through the cell to earth and might, therefore, affect the responder R. If with the switch set in the position shown in Fig. 1 the operator should detect the effects of static disturbances, he would throw the switch so as to cooperate with the contacts 2 and 3, thereby connecting the aluminum electrode E to the antenna and the carbon electrode to earth, in which position of said switch a negative electric charge developed in the antenna would pass to earth. Thus the position of the switch must be determined empirically by the operator in accordance with observed phenomena.

It will be noted that when the switch is set so that the cell will conduct a positive charge to earth the positive half waves developed in the antenna by the electromagnetic waves to be received will also be conducted to earth and will not assist in producing signals and that when the connections of the cell are reversed so as to conduct negative electric charges to earth the negative half waves developed in the antenna by said electromagnetic waves will also be conducted to earth, so that the static valve results in wasting approximately half the received energy. I have found, however, that the remaining energy absorbed by the antenna from the electromagnetic waves is sufficient to operate the responder, and I have been enabled with a

system provided with said static valve employed as above set forth to receive signals under conditions of static disturbance which otherwise would have rendered such reception impossible.

It will be noted that if, as indicated in Fig. 1, two static valves are employed with one antenna each must be connected so as to pass currents or charges of the same polarity, for if they were connected so as to pass currents or charges of opposite polarities one half the energy of the waves would pass to earth by way of one valve and the other half by way of the other. Generally but one valve will be sufficient, and while it may be connected to earth from either the point *a* or the point *b* (see Fig. 1) it is preferred to connect it to earth from the point *a*, so that its circuit will form a shunt around that portion of the antenna with which the responder circuit is associated.

The static valve shown at V' in Fig. 2 is another form of electrolytic asymmetric resistance consisting of two cups Q Q' of insulating material, the cup Q containing two electrodes D D' of the same materials as above set forth in connection with the static valve V of Fig. 1 and also containing one electrode E' of the same materials as the electrode E of the said valve V, and the cup Q' containing one electrode D and two electrodes E E' of the same materials, respectively as the electrodes of the cup Q.

The operation is as follows. When the receiving operator perceives that static effects are interfering with the reception of signals, he throws the switch S' over to the contacts 7 8 of the device Q and if the static effects are positive they will pass to earth E' by way of contact 7, carbon electrode D, and aluminum electrode E', while the negative half waves developed in the antenna by the electromagnetic signal waves will pass to earth E by way of the contact 8, electrode D, the electrolyte, electrode D', contact 8, and inductance L, thereby causing oscillations in the tuned receiving-circuit C R L and operating the receiver. If, however, the said static effects continue to interfere with the reception of signals when the device Q is connected in circuit, as above set forth, the receiving operator will know that the static effects are negative and will therefore proceed to throw the switch over to the contacts 9 10, in which case said negative static effects will pass to earth E' by way of the contact 9, aluminum electrode E', and carbon electrode D, while the positive half waves developed in the antenna by the electromagnetic signal waves will pass to earth E by way of the contact 10, electrode E, the electrolyte, electrode E', contact 10, and inductance L, thereby creating oscillations in the tuned receiving-circuit C R L and operating the receiver.

It will be seen in view of the foregoing that

any electrical rectifier, asymmetric resistance, or "electric valve," electrolytic or otherwise, may be utilized in carrying out the above-stated objects of my invention, and I shall now describe several forms of electric valve that are not electrolytic in nature.

The device  $V^1$ , (shown in Fig. 1,) connected between the antenna at the point  $b$  and earth, is an asymmetric resistance or electric valve which has been fully described by J. A. Fleming in a paper published in the *Proceedings of the Royal Society of London*, March 16, 1905, to which reference may be had for a more complete description thereof than need be set forth herein. Suffice it to say that the exhausted glass vessel  $Q^1$  contains the filament  $F^1$ , heated to incandescence by the battery  $B^1$ , and a metal cylinder  $D^1$ , which surrounds said filament  $F^1$ . This type of valve passes positive electricity from the cold terminal  $D^1$  to the heated terminal  $F^1$  more readily than in the opposite direction, and hence when the switch  $S^1$  makes contact, as shown in Fig. 1, with the contacts 5 and 6 positive static effects will pass to earth by way of the elements  $D^1$  and  $F^1$  of said valve, while if the connections be reversed by throwing the switch so as to contact with 4 and 5 negative static effects will pass to earth by way of the elements  $F^1$  and  $D^1$  of said valve.

In Figs. 4 and 4<sup>a</sup> the valves  $V^{IV}$  and  $V^V$  depend upon somewhat the same principle as the valve  $V^1$ . In these figures  $H$  is a lamp or Bunsen burner, the flame of which may be made more conducting by the addition of sodium or other salts, and  $J$  is a conductor placed near said flame.  $M$  is a bunch of asbestos or mineral wool which may be attached to said conductor  $J$ . In these devices positive electricity passes more readily from the element  $J$  to the flame, and hence to earth  $E^1$ , than in the opposite direction.  $S'''$  is a reversing-switch whose function is the same as that of the switch  $S$ .

In Fig. 5 the device  $M^1$  consists of mineral wool or asbestos placed between two plates and heated by the lamp  $H$ . This device is practically non-conducting when cold, but becomes a partial conductor when heated. The oscillations developed in the antenna by the electromagnetic signal-waves will have but little tendency to pass to earth by way of the shunt  $a^1$   $M^1$   $E^1$ , but heavy static charges induced in the antenna have an effect on the device  $M^1$  somewhat analogous to the phenomenon of coherence (although it is not a contact device) in that they increase the conductivity of said device, so that the latter becomes a very efficient static leak. The passage of the heated gases from the lamp  $H$  through the fibrous material of the device  $M^1$  maintains said device in its sensitive high-resistance condition, and thereby prevents the shunting around to inductance  $L$  of the oscillations intended to operate the responder.

In Fig. 3 I have shown still another static leak  $V^{III}$ , which I have effectively employed for the purpose of carrying my invention into effect. In this figure the arrangement of receiving-circuits is the same as in Fig. 1, and from the point  $a$  I connect to earth  $E$  a shunt-circuit including the adjustable inductance-coil,  $L$  of iron or other paramagnetic material or of a non-magnetic material plated with a paramagnetic material or of a non-magnetic material having a paramagnetic core. Such an inductance opposes enormous impedance to the passage of the high-frequency oscillations developed in the receiving system by the electromagnetic signal-waves, but offers but little impedance to the passage of the slow frequency or practically unidirectional currents resulting from the static charges induced in said system by atmospheric electricity, and hence eliminates the effect of said currents on the receiver.

By the term "static valve" as used in the specification and claims of this application I desire to be understood as meaning means offering greater opposition to electric currents of one character than to electric currents of different character, such, for example, as the asymmetric resistances described in connection with Figs. 1, 2, 4, and 4<sup>a</sup>, the spiral  $L$ , described in connection with Fig. 3, and the coherer-like device  $M$ , described in connection with Fig. 5; but it is to be understood that the particular devices hereinbefore specifically described are merely examples of a few of the static valves which may be employed for the purposes of the present invention.

I claim—

1. In a wireless-telegraph receiving system, the combination with an oscillation-detector of an electrolytic static valve.

2. In a wireless-telegraph receiving system, an oscillation-detector and an electrolytic static valve so associated therewith as to protect the same from static effects.

3. In a wireless-telegraph receiving system, a receiving-antenna, an inductance included therein, a tuned receiving-circuit associated with said inductance, an oscillation-detector in said tuned receiving-circuit, and means offering greater opposition to electric currents of one character than to electric currents of different character connected between the earth and a point in said antenna above the point of connection of said inductance to said antenna.

4. In a wireless-telegraph receiving system, an oscillation-detector, and means offering greater opposition to electric currents of one polarity than to electric currents of the opposite polarity so associated with said detector as to protect said detector from the effects of the currents of that polarity to which said means offers the greater opposition.

5. In a wireless-telegraph receiving system, an oscillation-detector, and an asymmetric resistance so associated therewith as to protect the same from static effects.

6. In a wireless-telegraph receiving system, an oscillation-detector, a static valve connected therewith and means for reversing the connections of the terminals of said static valve with said oscillation-detector.

7. In a wireless-telegraph receiving system, an oscillation-detector, an asymmetric resistance so connected therewith as to protect the same from static effects, and means for reversing the connections of the terminals of said asymmetric resistance with said oscillation-detector.

8. In a wireless-telegraph receiving system, an oscillation-detector, and an electrolytic asymmetric resistance so associated therewith as to protect the same from static effects.

9. In a wireless-telegraph receiving system, an oscillation-detector, an electrolytic asymmetric resistance so connected therewith as to protect the same from static effects, and means for reversing the connections of the terminals of said electrolytic asymmetric resistance with said oscillation-detector.

10. In a wireless-telegraph receiving system, a receiving-antenna, an oscillation-detector associated therewith, and an electrolytic static valve connected between the earth and a point in said antenna above the point of association of said detector with said antenna.

11. In a wireless-telegraph receiving system, a loop antenna, an inductance included in each side thereof, an oscillation-detector associated with said loop antenna, a connection from each side of said loop antenna around each said inductance to earth and a static valve in each said connection.

12. In a wireless-telegraph receiving system, a loop antenna, an oscillation-detector associated therewith, a static valve associated with each side thereof, and means for reversing the connections of each said static valve with its respective side of said loop antenna.

13. As a static valve for a wireless-telegraph receiving system, an electrolytic asymmetric resistance.

14. As a static valve for a wireless-telegraph receiving system, an asymmetric resistance.

15. In a wireless-telegraph receiving system, a loop antenna, an inductance included in each side thereof, an oscillation-detector associated with said loop antenna, a connection from one side of said loop antenna around one inductance to earth and a static valve in said connection.

16. In a wireless-telegraph receiving system, a loop antenna, an inductance included in each side thereof, a tuned receiving-circuit associated with said loop antenna, an oscillation-detector in said tuned receiving-circuit, and a static valve connected between the earth and a point in said antenna above the point of connection of said inductance to said antenna.

17. In a wireless-telegraph receiving system, a receiving-antenna, an inductance included therein, a tuned receiving-circuit associated with said inductance, an oscillation-detector in said tuned receiving-circuit, and a static valve connected across the terminals of said inductance.

In testimony whereof I have hereunto subscribed my name this 6th day of December, 1905.

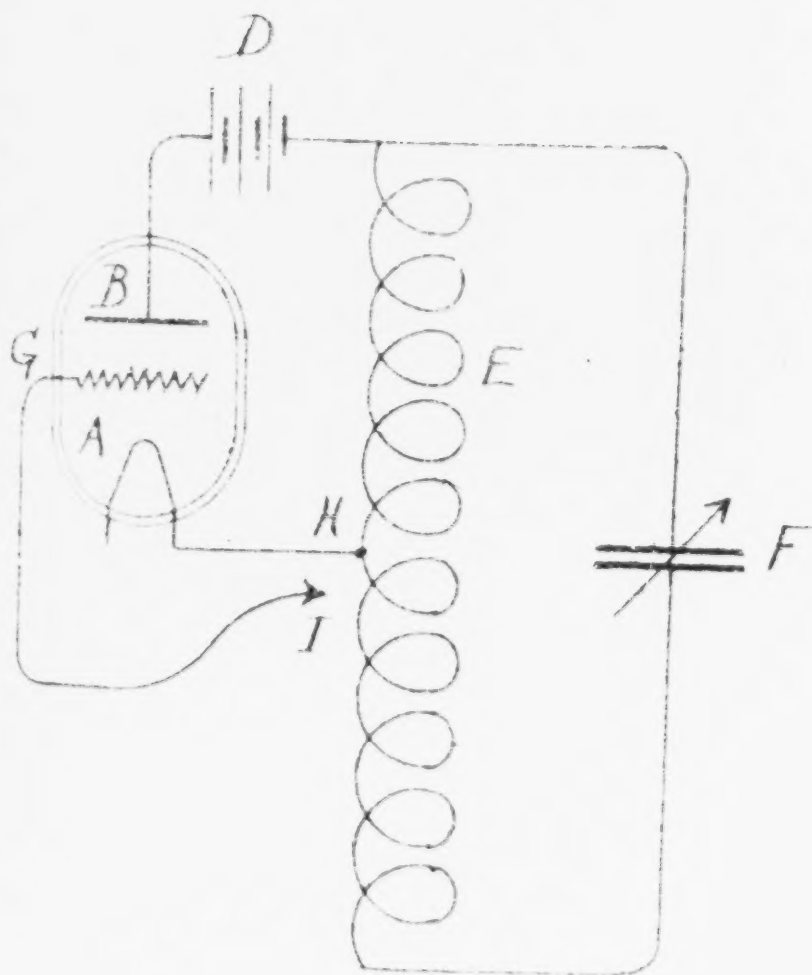
LEE DE FOREST

Witnesses:

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Claimant's Exhibit No. 259



Weagant Sketch No. 4

# PLAINTIFF'S EXHIBIT 260

15100

M. I. PUPIN AND E. H. ARMSTRONG.

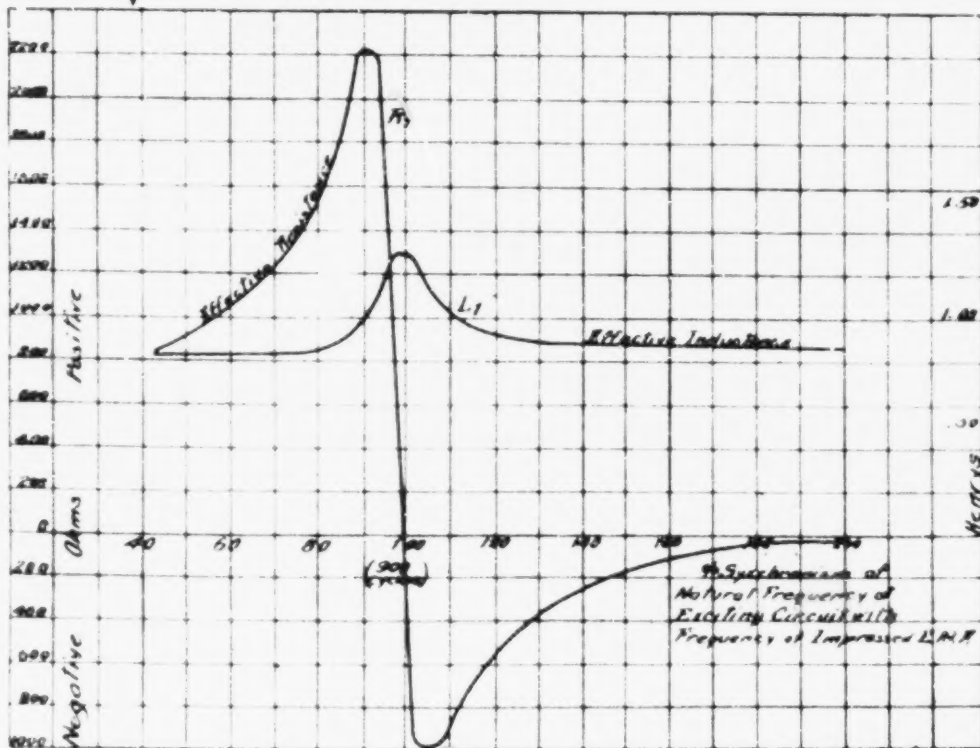
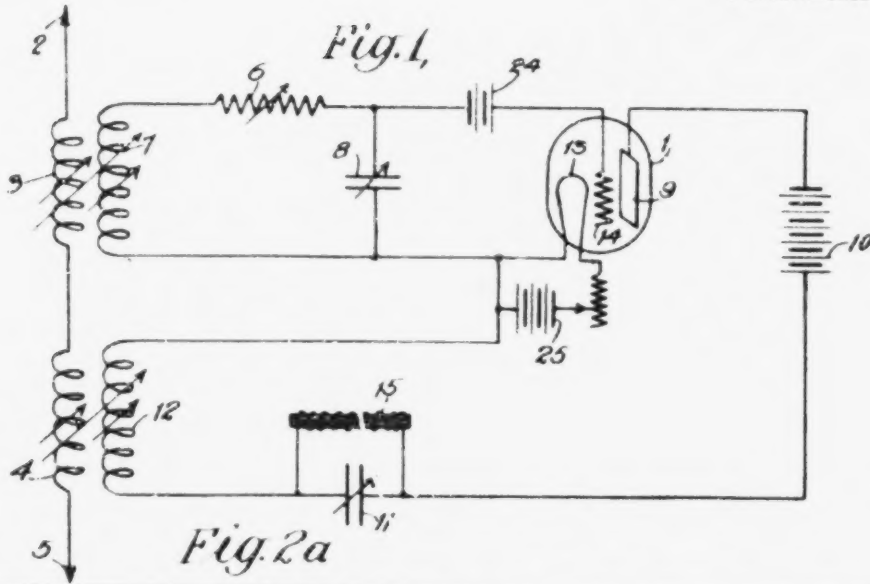
ELECTRIC WAVE TRANSMISSION.

APPLICATION FILED SEPT. 17, 1915.

1,334,165.

Patented Mar. 16, 1920.

8 SHEETS—SHEET 1.

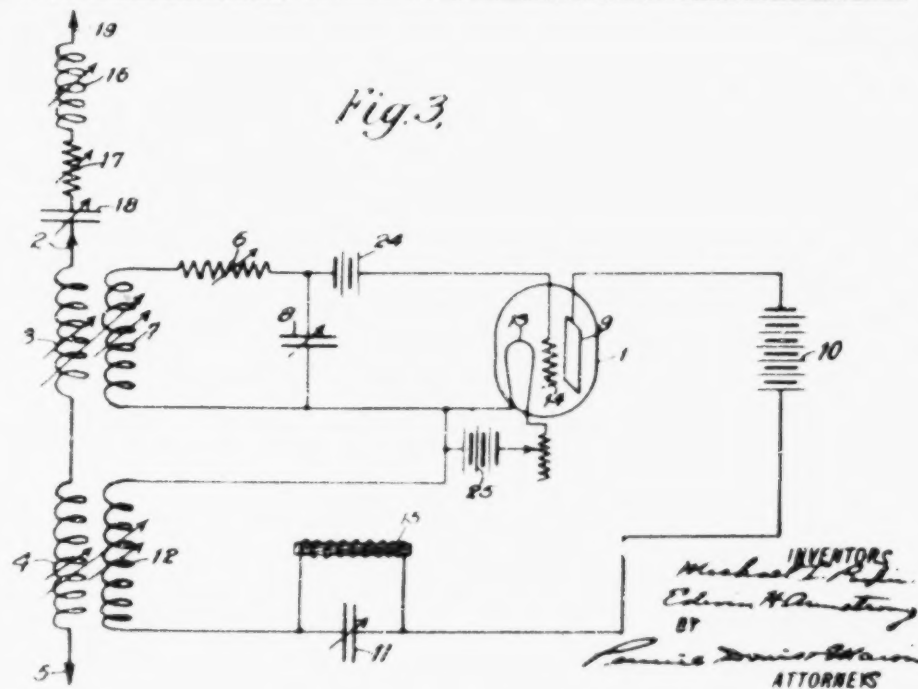
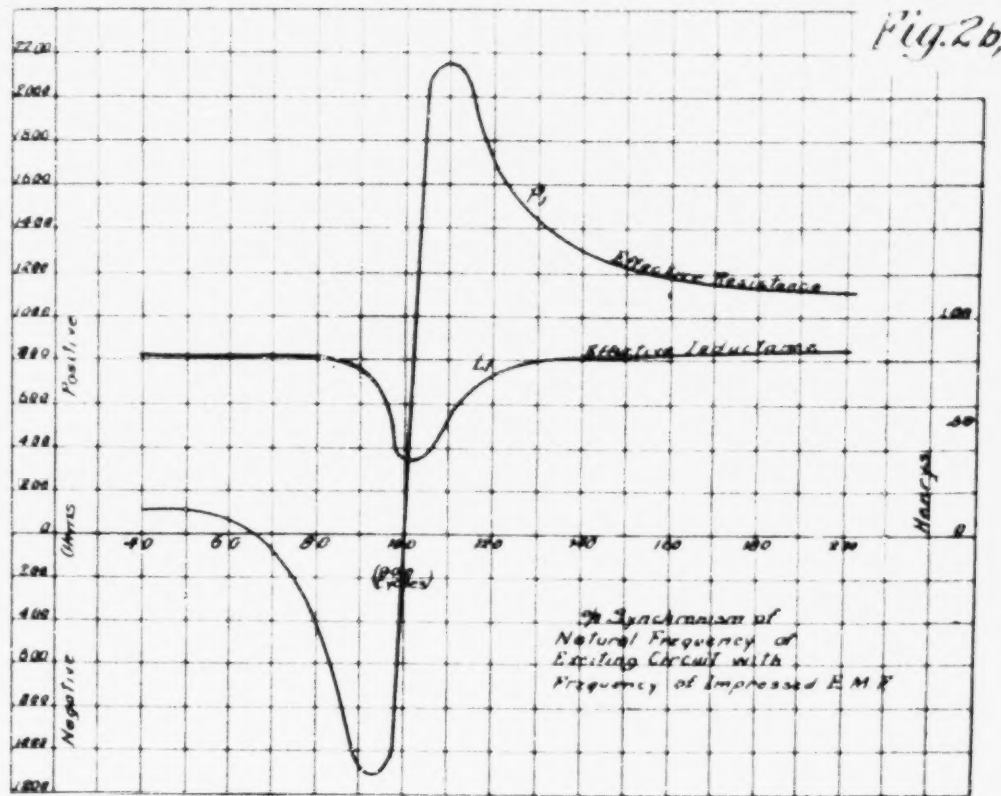


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1,334,165.

Patented Mar. 16, 1920.

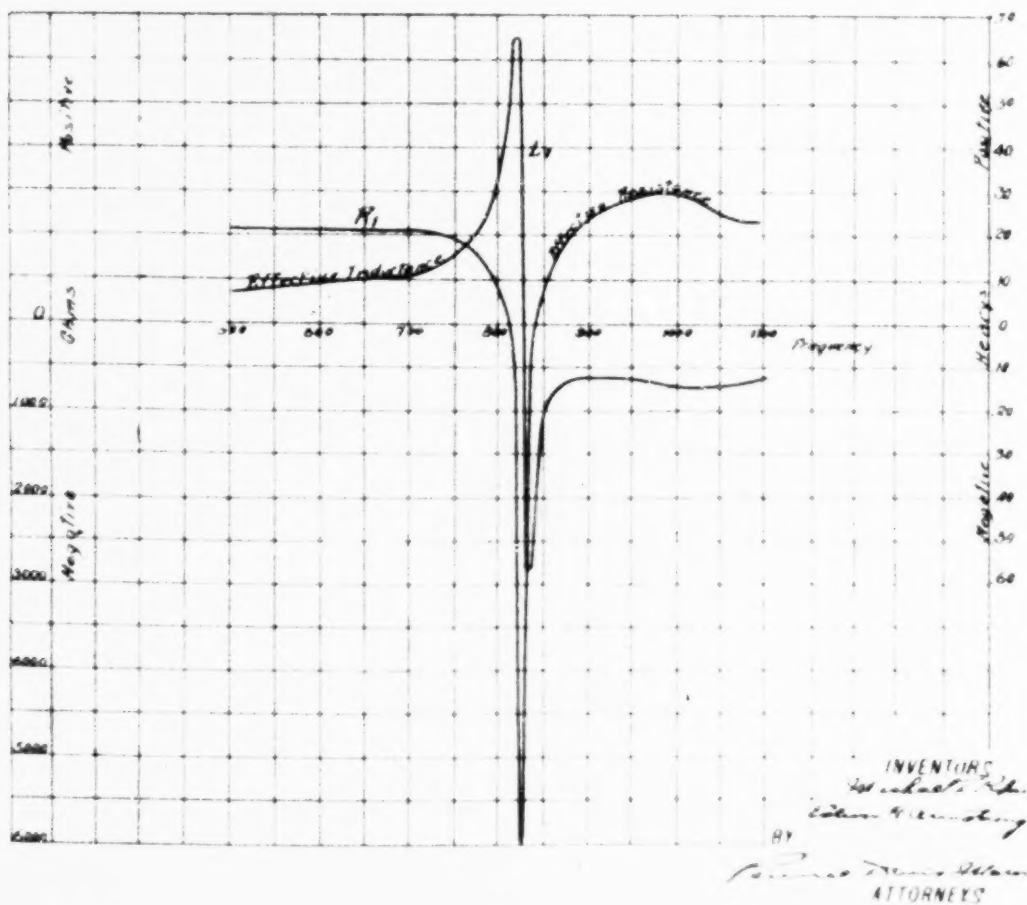
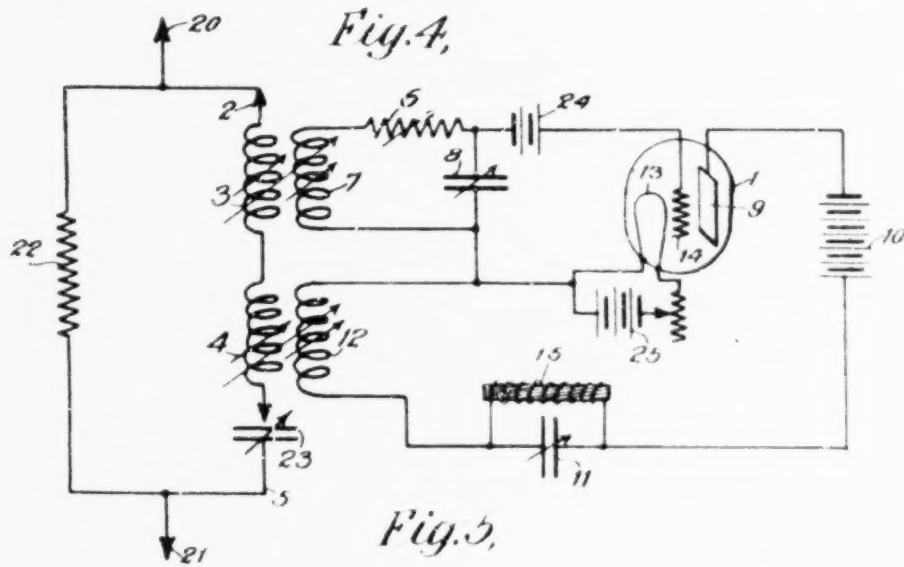
8 SHEETS SHEET 2



1,334,165.

Patented Mar. 16, 1920.

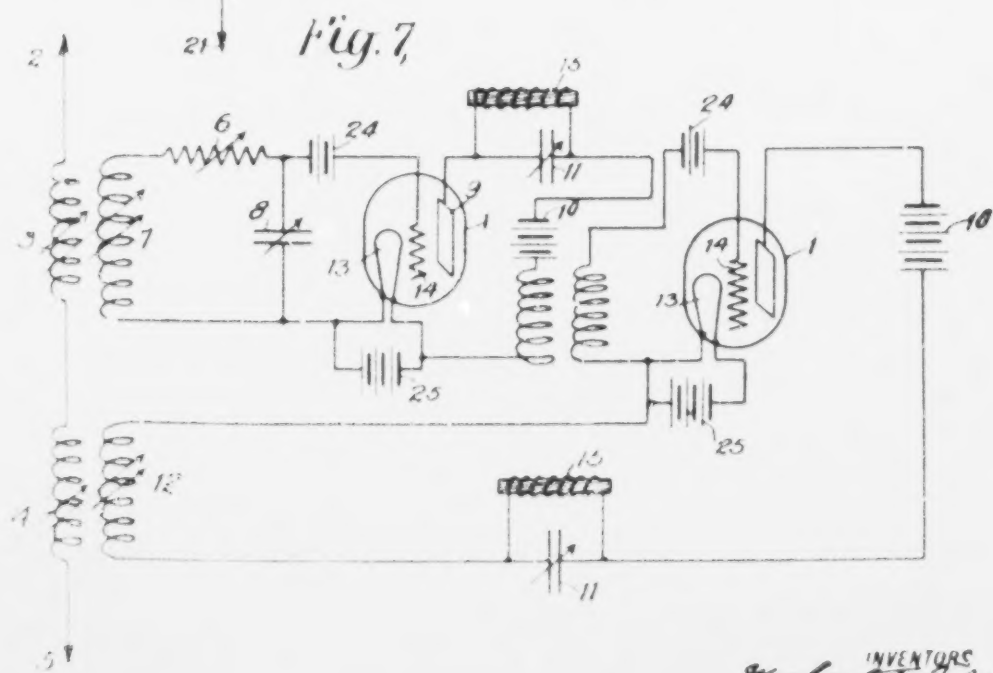
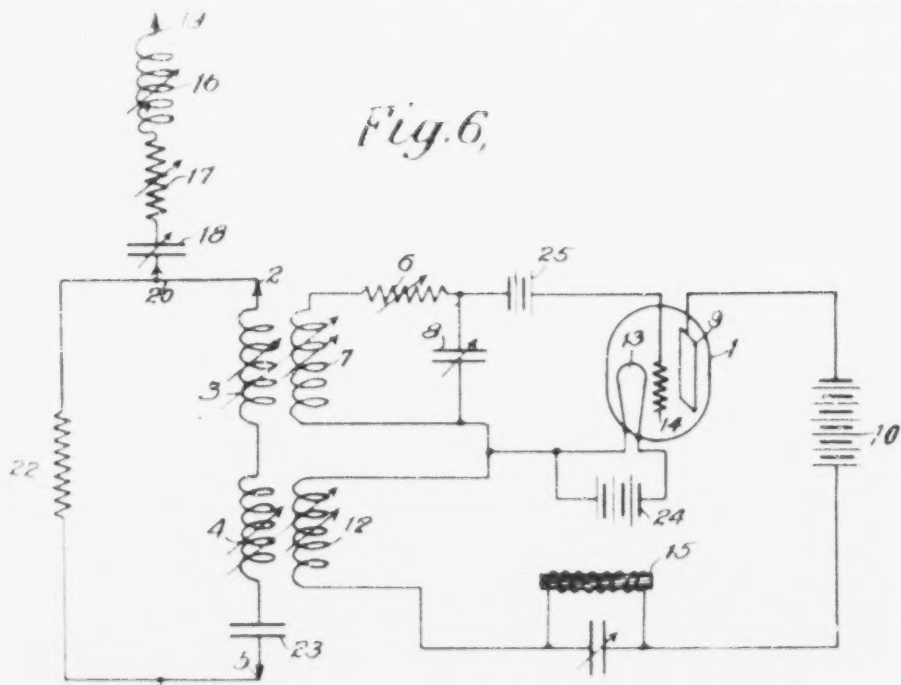
6 SHEETS—SHEET 3



1,334,165.

Patented Mar. 16, 1920.

6 SHEETS SHEET 4

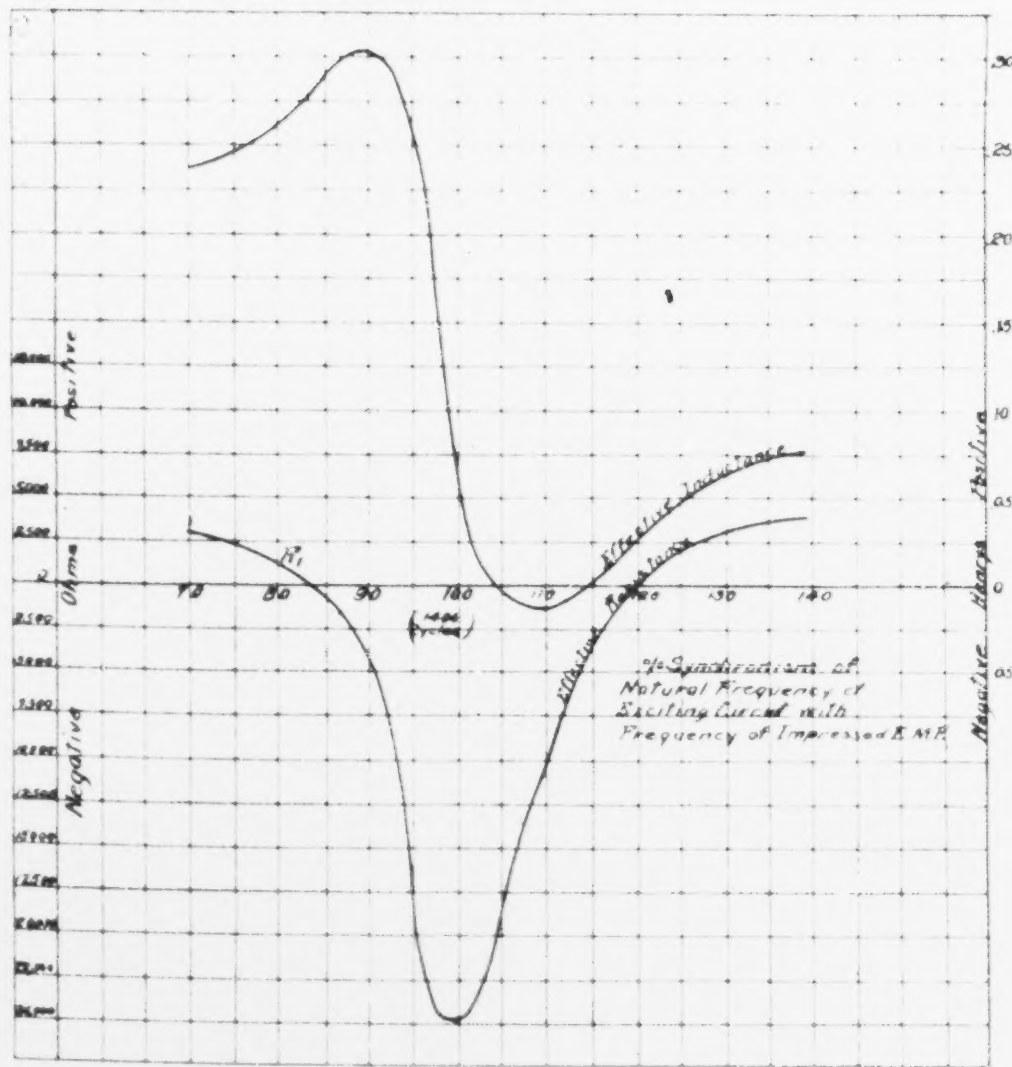


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1,334,165.

Patented Mar. 16, 1920.  
6 SHEETS—SHEET 5

Fig. 8.



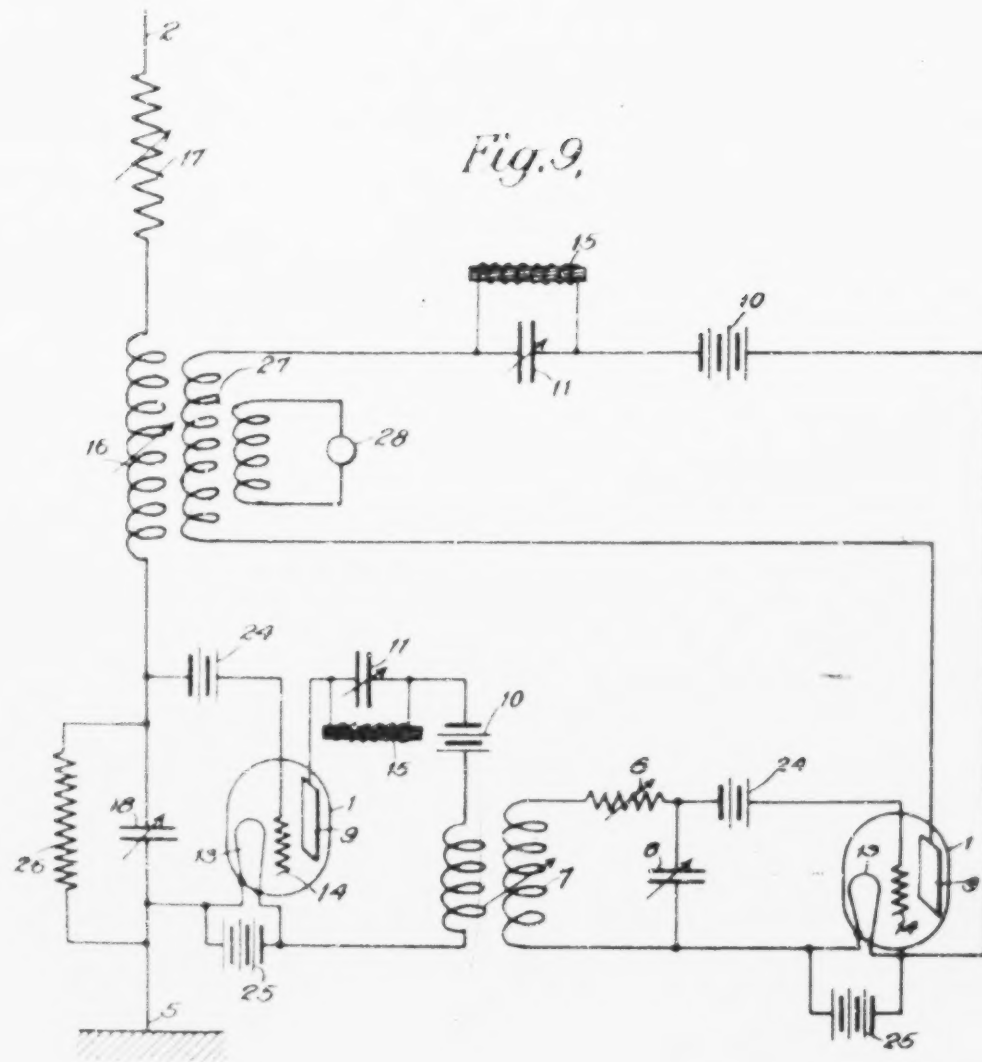
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1,334,165.

Patented Mar. 16, 1920.

6 SHEETS—SHEET 8

Fig. 9.



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# UNITED STATES PATENT OFFICE.

MICHAEL I. PUPIN, OF NORFOLK, CONNECTICUT, AND EDWIN H. ARMSTRONG, OF YONKERS, NEW YORK.

## ELECTRIC-WAVE TRANSMISSION.

1,334,165.

Specification of Letters Patent.

Patented Mar. 16, 1920.

Application filed September 17, 1915. Serial No. 51,151.

*To all whom it may concern:*

Be it known that we, MICHAEL I. PUPIN, a citizen of the United States, residing in Norfolk, county of Litchfield, State of Connecticut, and EDWIN H. ARMSTRONG, a citizen of the United States, residing in Yonkers, county of Westchester, State of New York, have invented certain new and useful Improvements in Electric-Wave Transmissions; and we do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to the production of a negative resistance reaction by means of a system of circuits containing a local source of electrical power with means for controlling it, and the application of this negative resistance reaction to the compensation of the resistance reaction of electrical conductors in order to make them responsive to sustained electrical waves of a predetermined frequency and not responsive to electromotive forces of a disturbing character. The apparatus described here is, briefly stated, a new form of resistance compensator operating in a generic sense similarly to the resistance compensator described by Michael I. Pupin in his copending application, Serial No. 51,150 filed September 17, 1915.

Referring to the diagrams which form a part of our specification, Figure 1 illustrates a system for producing the aforesaid negative resistance reaction, and Figs. 2<sup>a</sup> and 2<sup>b</sup> show curves of its resistance and reactance characteristics for various frequencies. Fig. 3 shows a method of applying the resistance compensator to reduce the effective resistance of a conductor. Fig. 4 shows a system of magnifying the negative resistance reaction produced by the system of Fig. 1 by means of a magnifying shunt placed around the main conductor of the compensator, and Fig. 5 illustrates the resistance and reactance characteristics obtained with a shunted compensator. Fig. 6 illustrates the method of applying the shunted compensator to the tuning of a conductor. Fig. 7 represents a compensator consisting of a plurality of parts connected in cascade system for the purpose of producing very large values of negative resistance. The characteristics of this system are illustrated by the curves of

Fig. 8. Fig. 9 illustrates the application of the resistance compensator to a wireless antenna.

In the particular arrangement illustrated in Fig. 1, an electrical valve 1 is coupled with the main conductor 2, 3, 4, 5 on the input side by means of the circuit 6, 7, 8, and on the output side by the circuit 9, 10, 11, 12. The electrical valve illustrated here is the well known vacuum tube containing a hot cathode 13 and a cold anode 9, between which a direct current flows, and a third electrode or "grid" 14 between them modifying the normal direct current between the hot cathode and the cold anode. The external impulses are conveyed to the valve by the circuit 6, 7, 8, which will be referred to as the "exciting circuit." By adjusting the constants of the exciting circuit 6, 7, 8, with respect to the frequency of the incoming waves, the excitation of the valve is regulated. The other circuit 13, 12, 15, 10, 9, contains an electrical battery 10 which maintains a direct current between the hot cathode 13 and the cold anode 9. The incoming waves vary the electrical potential of the grid 14 and thereby the direct current. This variation produces an electromotive force in the main conductor 2, 3, 4, 5, by mutual induction between 4 and 12, whereby energy is transferred from the battery 10 to the main circuit. It is this transfer of energy which manifests itself through a reaction between 2, 5, which has all the properties of a negative resistance reaction. This second circuit with its battery 10 through which the electrical valve is connected to the main conductor will therefore be referred to in this specification as the "energizing circuit."

It will be seen that in the arrangements described herein we have produced results by operations which are generically similar to those of the induction motor resistance compensator described in the above mentioned Pupin application, in which the primary circuit of the induction motor receives the incoming waves and produces thereby the magnetic excitation, whereas the rotating secondary by its electromagnetic reactions transfers by expenditure of mechanical energy electrical energy to the primary and thereby produces in it a negative resistance reaction. The amount of the negative resistance reaction produced by the means employed in the present case depends upon the

relation of the constants of both the exciting and energizing circuit to the frequency of the incoming waves, and for the purpose of adjusting these constants, variable inductances 7 and 12 and capacities 8 and 11 and a variable resistance 6 are employed. In other words, these circuits are capable of tuning.

The effective resistance and the effective inductance of the system of Fig. 1 between the points 2 and 5 as measured by a Wheatstone bridge employing an alternating electromotive force of suitable frequency, may be either as in Fig. 2<sup>a</sup> or Fig. 2<sup>b</sup>, depending on the polarity of connection of the transformers 2, 7, and 4, 12. In Fig. 2<sup>a</sup> the maximum negative resistance in the main conductor is developed at a frequency below, and in Fig. 2<sup>b</sup> the maximum negative resistance is developed at a frequency above the frequency for which the exciting circuit when taken by itself is non-reactive.

The negative resistance reaction in the main conductor 2, 3, 4, 5, is produced in the system of Fig. 1 by the following operations. A current in the main conductor 2, 3, 4, 5, induces an e. m. f. in circuit 6, 7, 8, an electron stream force which charges the condenser 8 and the grid 4 connected to it. The charged grid produces a variation in the amplitude of the stream current flowing through the conductive channel 10, 13, 12, 13, 9. This current variation then induces an e. m. f. in the main conductor 2, 3, 4, 5.

The present system of tuning the current in the main conductor 2, 3, 4, 5, by an electron stream force determines the reactions which are produced in the main conductor. If the electromotive force thus produced in the main conductor is so constituted in phase that one of its two components is in the same phase with the current in the main conductor, then a resultant negative resistance reaction between 2 and 5 appears when this electromotive force component is greater than the effective positive resistance reaction of the coils 3 and 4. The value of this negative resistance reaction depends only upon the amount of current variation produced by the action of the grid 4 and upon the process of mutual induction between the main current and its secondaries. The law in accordance with which this value of the negative resistance reaction may be varied, and given any assigned limit, is discovered by connecting the terminals 2, 5, of the main conductor as represented in Fig. 1 into an arm of a Wheatstone bridge employing alternating electromotive force of suitable frequency and intensity. The curves illustrated by Figs. 2<sup>a</sup> and 2<sup>b</sup> are a result of a study of this kind. In these figures, the ordinates of curve R represent the effective resistance and of curve L, the effective inductance between the terminals 2, 5, for

various frequencies. It will be seen that these curves are in their main features, similar to those obtained with the induction motor compensator described in the previous application referred to. No exact general mathematical formula can be given which will express the relation between the effective resistance and effective reactance of the main conductor and the electromagnetic constants of the various parts of the system and the impressed frequency. But an experimental study by means of a Wheatstone bridge enables one to construct easily an empirical formula for any particular case.

To apply this negative resistance reaction to the compensation of the resistance reaction of an electrical conductor, we proceed in the manner indicated in Fig. 3. Here 16, 17, 18, is a conductor containing resistance, inductance and capacity and which is to be tuned to the frequency of an impressed simple harmonic electromotive force. The main conductor 2, 3, 4, 5, of the resistance compensator is placed in series with the conductor 16, 17, 18, and the coils 6, 7, 8, adjusted to produce negative resistance between the points 2, 5, at the frequency for which the conductor 16, 17, 18, is to be made selective. The value of the negative resistance between 2 and 5 is adjusted to be slightly less than the positive resistance of the conductor 16, 17, 18, so that the resultant effective resistance of the conductor 16, 17, 18, is very much reduced for the correct frequency. This has been explained at greater length in the previous application referred to. The negative resistance may be varied by adjusting the coupling between 4 and 12, or 3 and 7, or by varying the power of the valve to vary the grid direct current, or by varying the value of the resistance 6. As the main function of the resistance 6 is to control the steepness of the resistance curves R, in Figs. 2<sup>a</sup> and 2<sup>b</sup> in the vicinity of their negative maxima and thereby vary the sharpness of tuning of the system, it is better to vary one of the couplings to obtain the required variation in negative resistance. The reactance of the main conductor is adjusted to zero for the same frequency by means of the inductance 16 or the condenser 18.

For the right frequency, the conductor 16, 17, 18, therefore, has zero reactance, and an effective resistance which is only a small fraction of the resistance added to it, but for all other frequencies, both the resistance and the reactance are relatively very large. The amount of positive resistance that can be added in this way is limited by the capacity 18 of the resistance compensator and by nothing else.

The arrangement of the present application lends itself to magnification of the resistance reaction by means of a shunt or by

other well known means of potential magnification by transformation in the same manner as the arrangement of the Pupin application referred to, does.

This may be done by the arrangement represented by the diagram of Fig. 4. In this arrangement which is the counterpart of the arrangement of Fig. 3 of the previous application referred to above, a non-inductive shunt containing resistance 22 is placed across the conductor in which the negative resistance is produced. This conductor is provided with a series condenser 23 for the purpose of adjusting the effective reactance of the conductor. When the shunt positive resistance is made slightly greater than the shunted negative resistance, a large multiplication of the original negative resistance is obtained in the manner explained in the previous application. A shunt of 1200 ohms placed across the conductor having the characteristic of Fig. 2<sup>a</sup> gives a multiplication of above six times. The characteristic resistance and reactance curves are shown in Fig. 5.

To apply the shunted valve system for the purpose of compensating the resistance reaction of a conductor, we connect the conductor 20, 21, in series with the conductor 16, 17, 18, as illustrated in Fig. 6. The adjustments of resistance and reactance of the main conductor are made in the manner previously described for the simple resistance compensator.

Another method of producing a high negative resistance is by means of a resistance compensator consisting of a plurality of parts in cascade as depicted in Fig. 7. Two parts are shown here, but any number of parts may be used to produce any required value of negative resistance reaction in the main conductor providing due regard is paid to the proper adjustment of the phase of the mutual inductance reaction between the energizing circuit and the main conductor. The characteristics of the particular arrangement of Fig. 7 are illustrated by the curves of Fig. 8.

In the present application, as in the previous application referred to, the arrangement for producing negative resistance should preferably be such that the full value of the negative resistance cannot be produced instantaneously; that is, a certain definite length of time should elapse after the arrival of the initial impulse of a train of waves before the transient electrical state has passed into the stationary state in which the full maximum value of negative resistance is established. This length of time is determined by the duration of the transient state of the exciting circuit, and may be regulated by suitable adjustment of the resistance of this circuit which determines the rate of damping of its free oscillation.

To apply the resistance compensator to the reduction of atmospheric disturbances, we prefer to arrange the apparatus as in Fig. 9, in which a resistance compensator containing a plurality of electron discharge elements is arranged to produce in the antenna a high negative resistance reaction. The first part is connected to the antenna by means of a condenser 18 which is located at the base of the antenna and is shunted by resistance 26 which constitutes a leakage path for electrostatic charges accumulating on the antenna. The particular advantage of the specified connection of 17, 16 and 18 is that the condenser 18 is shielded by the high resistance 17 and the inductance 16 from pulses of short duration which are unable to develop any appreciable reaction across the condenser and thereby excite the compensator. The second part of the resistance compensator is connected to the antenna through the transformer 16, 27, and an electrostatic transformer 28 or any other detecting device is inductively associated with the coil 27.

As explained in the previous application, the shunt employed for magnifying the negative resistance reaction offers a means for shielding the induction motor from the direct effects of electrical impulses. We find the same advantages are secured by the use of the shunt with the present form of resistance compensator in the manner previously described.

What we claim is:

1. In a receiving system for electromagnetic waves, a receiving conductor into which is introduced a resistance sufficiently high to screen the system effectively against disturbing electromagnetic waves impressed upon the conductor in combination with a resistance compensator consisting of an electrical power source and means for selectively transferring power from this source to the conductor by producing in the conductor a negative resistance reaction sufficiently large to compensate to any desirable limit the losses due to the dissipative resistance introduced into the receiving conductor.

2. In a wireless receiving system a wave conductor for the reception of electrical waves into which is introduced a resistance sufficiently great to make its resistance reaction large in comparison with its inductance reaction for all frequencies which are important in wireless wave transmission in combination with a resistance compensator consisting of an electrical power source and controlling means excited by the incoming waves for transferring power from the power source to the conductor to supply it with a compensating negative resistance, the resistance compensator being responsive to a sustained impressed electromotive force

and substantially unresponsive to an impressed electromotive force of short duration.

3. In a wireless receiving system a wave conductor for the reception of electrical waves into which is introduced a resistance sufficiently great to make its resistance reaction large in comparison with its inductance reaction for all frequencies which are important in wireless wave transmission in combination with a resistance compensator consisting of an electrical power source and controlling means excited by the incoming waves for transferring power from the power source to the conductor to supply it with a compensating negative resistance, the resistance compensator being selectively responsive to a sustained impressed electromotive force and substantially unresponsive to an impressed electromotive force of short duration.

4. A receiving system for electrical waves consisting of a receiving conductor with which has been associated a resistance sufficiently large to screen the system effectively against disturbing electromagnetic waves impressed upon the antenna and a resistance compensator having an exciting circuit which is connected across a condenser in series with the receiving conductor so that the direct effect of electrical impulses of short duration on the compensator is greatly reduced.

5. A receiving system for electrical waves consisting of a receiving conductor with which has been associated a resistance sufficiently large to screen the system effectively against disturbing electromagnetic waves impressed upon the antenna, a resistance compensator deriving its power from an electrical power source and connected to said conductor and a magnifying shunt across the said compensator containing a resistance of such value that the resultant negative resistance reaction of the combined circuits will be greater than the original negative resistance reaction to magnify the negative resistance reaction introduced into the main conductor and to shield the compensator from the direct effect of electrical impulses.

6. A resistance compensator consisting of a plurality of parts connected in cascade each part having an exciting circuit and an energizing circuit with an electrical power source, the exciting circuit of the first part being connected to a wave conductor, and the energizing circuit of each part being connected to the exciting circuit of the succeeding part, except the last part, the energizing circuit of which is connected to the wave conductor, and in which at least one of the exciting circuits is tuned, whereby there is selectively imparted to the wave conductor a high negative resistance reaction.

7. A resistance compensator consisting of a plurality of parts connected in cascade each part having an exciting circuit and an energizing circuit with an electrical power source, the exciting circuit of the first part being connected to a wave conductor, and the energization circuit of each part being connected to the exciting circuit of the succeeding part, except the last part, the energizing circuit of which is connected to the wave conductor, and in which at least one of the exciting circuits is tuned, and one of them having the characteristic that impulses imparted to it produce their full exciting effect after a predetermined time interval only.

8. A receiving conductor into which has been introduced a resistance sufficiently high to make its resistance reaction large as compared with its inductance reaction for all frequencies which are important in wireless wave transmission in combination with a resistance compensator consisting of a source of electrical power and means for transferring from the power source to the receiving conductor wave energy of substantially the same wave form as selected incoming waves and of potential sufficiently high to produce in the receiving conductor a negative resistance reaction which substantially compensates the losses due to the positive resistance introduced into said conductor.

In testimony we affix our signatures

MICHAEL I. PUPIN,

EDWIN H. ARMSTRONG

# PLAINTIFF'S EXHIBIT 261

3110

W. C. WHITE.

MEANS FOR PRODUCING HIGH FREQUENCY OSCILLATIONS.

APPLICATION FILED JUNE 3, 1918

1,393,594.

Patented Oct. 11, 1921.

Fig. 1.

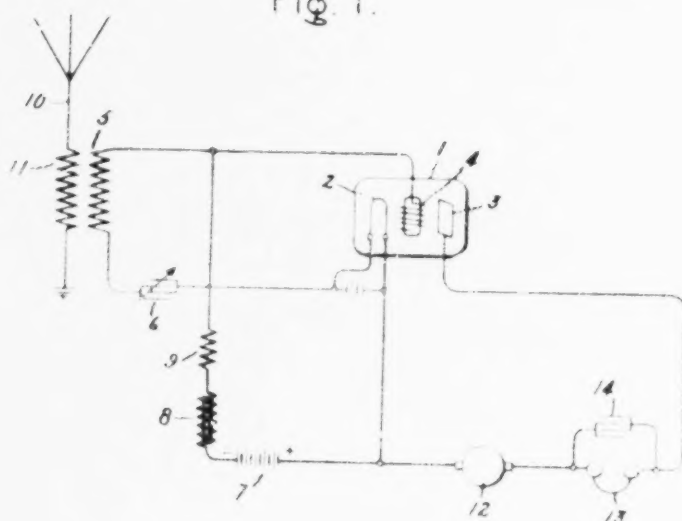
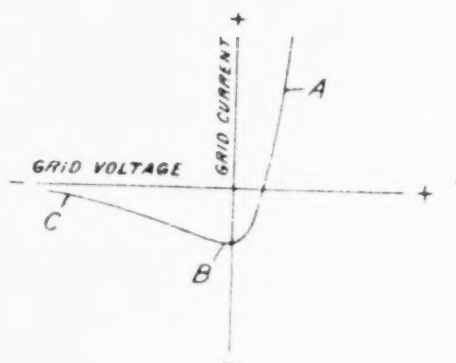


Fig. 2.



Inventor:  
William C. White,  
by *Alfred H. Davis*  
His Attorney.

# UNITED STATES PATENT OFFICE.

3111

WILLIAM C. WHITE, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

## MEANS FOR PRODUCING HIGH-FREQUENCY OSCILLATIONS.

1,393,594.

Specification of Letters Patent.

Patented Oct. 11, 1921.

Application filed June 3, 1918. Serial No. 237,845.

*To all whom it may concern:*

Be it known that I, WILLIAM C. WHITE, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Means for Producing High-Frequency Oscillations, of which the following is a specification.

My present invention relates to the production of high frequency oscillations by means of an electron discharge relay or amplifier, and more particularly to the application of oscillations thus produced in a radio receiving system of the well-known heterodyne type.

Electron discharge devices of the type comprising an evacuated container inclosing a filamentary cathode, a plate-shaped anode and a grid, interposed between cathode and anode, are well known. Various connections have also been employed with such devices to cause them to operate to produce high frequency oscillations. In all of the connections which have previously been used, however, so far as I am aware, the same fundamental principle has been employed, that is, a portion of the amplified energy in the plate circuit of the device has been fed back to the grid circuit by some form of coupling so as to make the system self-exciting.

In carrying my invention into effect, however, I employ a materially different principle. I have found that under certain conditions with devices of this type the current in the grid circuit may have a dropping characteristic, that is, as the voltage impressed upon the grid increases the current in the grid circuit will decrease. With the proper conditions for operation a circuit having current characteristic of the type described may be so organized that oscillations will be produced therein, the essential condition for the production of oscillations being that the circuit shall contain capacity and inductance and that the resistance of

the circuit shall be less than  $2\sqrt{\frac{L}{C}}$  where L represents the inductance and C the capacity of the circuit. Hence in carrying my invention into effect I provide the connections necessary to render the grid circuit resonant and thus cause the production of oscillations therein. While the current in the grid circuit is in all cases comparatively

small and hence the amplitude of the oscillations produced will be small the amplifying effect of the device will cause oscillations of much greater amplitude to be produced in the plate circuit. The maintenance of the oscillations, however, will be entirely independent of any coupling between the two circuits.

In utilizing my invention in a radio receiving system of the heterodyne type I produce in the grid circuit of the device oscillations of slightly different frequency from those which are to be received. The received oscillations may also be impressed upon the grid circuit and the two sets of oscillations be combined in that circuit to produce what are technically known as "beats." These beats will be reproduced in the plate circuit of the device and produce an audible response in the usual telephone receiver which is included in the plate circuit.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation will best be understood by reference to the following drawing in which Figure 1 illustrates diagrammatically the connections which may be employed in carrying my invention into effect, and Fig. 2 shows a characteristic curve of the current in the grid circuit of an electron discharge device which is so constructed and adjusted as to be suitable for carrying out my invention.

In the system illustrated in Fig. 1 I have indicated an electron discharge device 1 having the usual filamentary cathode 2, an anode 3 which may be plate shaped as shown or of any other desired form and a discharge-controlling grid 4 inclosed in a well evacuated receptacle. The grid circuit of this device includes an inductance 5 and a variable capacity 6. A battery 7 is provided for applying to the grid a potential at which the operation of the device may be suitable for the desired purpose.

Referring now to Fig. 2 the curve A indicates the current in the grid circuit of the device 1, with varying voltages on the grid. The abscissae of the curve represent voltage and the ordinates current. It will be noted that over a considerable range of voltage when the grid voltage is negative the cur-

rent in the grid circuit decreases with an increase of the negative grid voltage. That is, at the point B on the current curve which represents a very small negative voltage the current in the grid circuit is greater than at the point C, which represents a much larger negative grid voltage. This characteristic of the current curve is probably due to the effect of slight traces of residual gas in the device and the consequent positive ionization. The greater the negative grid voltage the lower the plate current and therefore the lower the amount of positive ionization in the device due to residual gas therein. As a result, therefore, the grid current will decrease by reason of the smaller number of positive ions which may reach the grid.

If the battery 7 is of such potential that the grid current will fall upon some portion of the current curve between the points B and C, oscillations will be produced in the grid circuit. The frequency of the oscillations produced may be readily varied by adjusting the condenser 6. Inductances 8 and 9 should be employed in series with battery 7 of such value that there will be no damping of the oscillating circuit due to the connection of the battery 7 across the circuit. With the device producing oscillations of the desired frequency oscillations received upon the antenna 10 may be impressed upon the inductance 5 by means of the coupling coil 11 which is included in the antenna circuit. The received oscillations will combine in the grid circuit with the locally produced oscillations in the well-known manner and produce beats. In other words, the potential of the grid 4 will oscillate and the amplitude of the oscillations will vary at a frequency corresponding with the beat frequency produced. As a result a beat current will be produced in the plate circuit of the device, energy for which is supplied by the direct current generator 12, and the beats in the plate current may be detected by the usual telephone receiver 13. The telephone receiver 13 may, if desired, be shunted by a capacity 14 for by-passing the radio frequency component of the current in the plate circuit.

I have found that in most cases fairly high potentials must be employed in the plate circuit in order to secure the desired operation. For example, with one particular device I have found that a plate potential of about 375 volts was necessary in order to secure the desired operating characteristic.

While I have illustrated only one circuit connection whereby oscillations may be produced, and have indicated but one use for the oscillations, it will be apparent that many modifications in the circuit connection employed as well as in the use to which

the oscillations are applied may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is—

1. Means for producing high frequency oscillations comprising an electron discharge device having an electron emitting cathode, an anode and a discharge controlling grid inclosed in an evacuated receptacle, a plate circuit which includes the cathode and anode of said device and a source of potential, a resonant grid circuit which includes the cathode and grid of said device, said device and its associated circuits being so constructed and adjusted that the current in the grid circuit will vary inversely as the applied potential over a given operating range of negative potential and a source of potential connected to the grid circuit of such value that the normal potential of the grid is within said operating range, whereby oscillations will be produced in said grid circuit independently of any coupling between grid and plate circuits.

2. Means for producing high frequency oscillations comprising an electron discharge device having a plate circuit and a resonant grid circuit, said device and its associated circuits being so constructed and adjusted that the current in the grid circuit will vary inversely as the applied potential over a given operating range of negative potential, and a source of potential connected to the grid circuit of such value that the normal potential of the grid is within said operating range, whereby oscillations will be produced in said grid circuit independently of any coupling between grid and plate circuits.

3. The combination in a radio receiving system of an electron discharge device having a plate circuit and a grid circuit which is resonant to a frequency differing by an amount within the range of audibility from the waves to be received, means for impressing received waves upon said grid circuit, said device and its associated circuits being so constructed and adjusted that the current in the grid circuit will vary inversely as the applied potential over a given operating range of negative potential, a source of potential connected to the grid circuit of such value that the normal potential of the grid is within said operating range whereby oscillations will be produced in said grid circuit independently of any coupling between grid and plate circuits which will combine with the received oscillations to produce beats and means for detecting the beats thus produced.

4. The combination in a radio receiving system of an electron discharge device having a plate circuit and a grid circuit which a

resonant to a different frequency from that of the waves to be received, means for impressing received waves upon said grid circuit, said device and its associated circuits being so constructed and adjusted that the current in the grid circuit will vary inversely as the applied potential over a given operating range of negative potential, a source of potential connected to the grid circuit of such value that the normal potential of the grid is within said operating range whereby oscillations will be produced in said grid circuit independently of any coupling between grid and plate circuits which will combine with the received oscillations to produce beats and means for detecting the beats thus produced.

5. The combination in a radio receiving system of an electron discharge device having a plate circuit and a grid circuit which is resonant to a frequency differing by an amount within the range of audibility from the waves to be received, means for impressing received waves upon said grid circuit, said device and its associated circuits being so constructed and adjusted that the current in the grid circuit will vary inversely as the applied potential over a given operating range of negative potential, a source of potential connected to the grid circuit of such value that the normal potential of the grid is within said operating range whereby oscillations will be produced in said grid circuit independently of any coupling between plate and grid circuit which will combine with the received oscillations to produce beats and means in the plate circuit of the device for detecting the beats thus produced.

6. The method of operating an electron discharge device having an electron emitting

cathode, an anode and a discharge controlling grid inclosed in an evacuated receptacle and having a plate circuit and a resonant grid circuit associated therewith which consists in generating high frequency oscillations in said grid circuit independently of any transfer of energy to said grid circuit from other circuits. 45

7. The method of receiving signals in a receiving system comprising an electron emitting cathode, an anode and discharge controlling grid inclosed in an evacuated receptacle and having a plate circuit and a resonant grid circuit associated therewith which consists in impressing received signaling currents upon said grid circuit, generating oscillations in said grid circuit of a frequency differing from that of the signaling currents independently of any transfer of energy to said grid circuit and thereby producing a beat current in said grid circuit and amplifying and detecting the beats thus produced. 60

8. The method of operating a signal receiving system comprising an electron emitting cathode, an anode and a discharge controlling grid inclosed in an evacuated receptacle and having a plate circuit and a resonant grid circuit containing a source of energy associated therewith which consists in generating high frequency oscillations in said grid circuit independently of any transfer of energy to said grid circuit from other circuits, and producing by the conjoint action of the locally generated oscillations and received oscillations an audio frequency current in the plate circuit. 75

In witness whereof, I have hereunto set my hand this 1st day of June, 1918.

WILLIAM C. WHITE.

## Claimant's Exhibit No. 262

the behavior of the dynatron in any circuit containing resistance, capacity, inductance and electromotive force can be accurately calculated by treating the dynatron as a linear conductor with negative resistance  $r$ . Examples of such calculations are given below.

The term  $i_0$  in the above equation disappears if the dynatron is connected in series with a battery, of voltage equal to that at which the dynatron current is zero (point  $B$ , Figure 3). The combination is a **true** negative resistance, for which  $i = \frac{E}{r}$ . For example, if the dynatron of Figure 1 be put, with its batteries, in a box, and two wires be brought out thru the box as terminals,

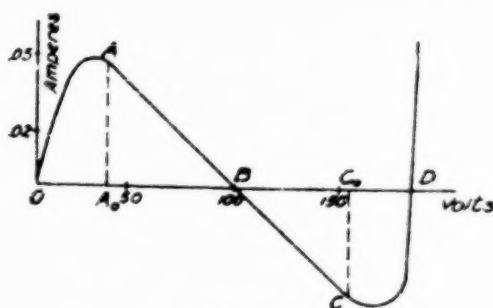


FIGURE 3

one from the plate  $P$  and one from a point  $V_0$  of the battery corresponding to the point  $B$  of Figure 3, this "negative resistance box" would behave in all respects like a conductor with negative resistance, over the range of voltage, positive and negative, represented by  $BC$ , and  $BA$ , in Figure 3.

The magnitude of the negative resistance, which is the slope of the current voltage curve, Figure 3, and the range of voltage  $A_0 - C_0$  over which it can be used, depends upon the anode voltage, the temperature of the filament, and, to some extent, on the shape and material of the electrodes. The effect of varying anode voltage alone is shown for two different types of tube in Figures 4 and 5, and the effect of varying filament temperature in Figure 6. It is seen that the effect of varying anode voltage is, in general, to shorten or lengthen the range of the negative resistance part of the curve, without changing the value of the negative resistance. A slight shift in the voltage  $V_0$  at which the curves cross the axis is, for one tube, to the right with increasing voltage, and for the other, to the left. It is

## Claimant's Exhibit No. 263

## THE THERMIONIC AMPLIFIER

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varied by varying any of the applied voltages. Another condition for equation (4) is that the grid should not become sufficiently positive to distort the characteristic. Under these conditions I have generally found this equation to hold sufficiently well, to a first approximation at least, and have been using it in connection with work on the amplifier tube. The above equation does, however, not hold sufficiently accurately for purposes of radiodetection, since this is determined by second order quantities.

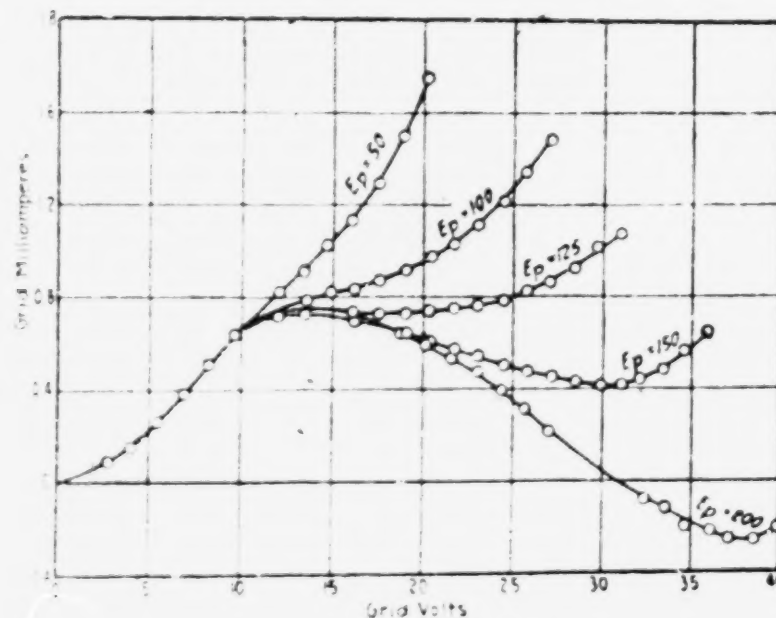


FIG. 75.

Latour<sup>1</sup> has derived some equations for the "relay effect" of diode tubes. He starts from the general functional expressions for the plate and grid currents:  $I_p = F(E_g, E_p)$  and  $I_g = f(E_g, E_p)$ . In the expansion of these equations he neglects all quantities of the second and higher order, thus assuming that the current and voltage variations are very small, or that the characteristic is linear over the operating range.

<sup>1</sup> M. LATOUR, *Electrician*, December, 1916.

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PLAINTIFF'S EXHIBIT 264

*THREE-ELECTRODE VACUUM TUBE AS AN AMPLIFIER 173*

the internal resistance of the battery  $B$ , but not the internal plate resistance  $R$  of the tube. The grid  $G$  is connected to the filament through a battery  $C$  which determines the operating point of the tube on the static characteristic curve, and through an alternator  $D$  which impresses between the grid and the filament the emf. to be amplified.

In order to facilitate reference, the following letter symbols used are tabulated.

$R$  = internal plate resistance of the tube.

$E_p$  = instantaneous difference of potential between grid and filament.

$E_b$  = instantaneous difference of potential between plate and filament.

$e_g$  = instantaneous alternating grid emf.

$E_b$  = plate battery emf.

$E_c$  = grid battery emf.

$I_p$  = instantaneous total current in the plate circuit.

$I_b$  = direct current component of the plate current.

$i_p$  = alternating current component of the plate current.

$Z$  = impedance of the external plate circuit.

$r$  = resistance of the external plate circuit.

$k$  = amplification factor of the tube.

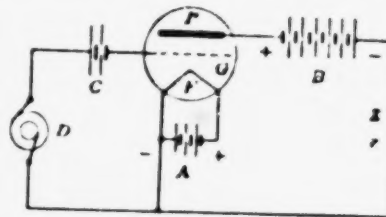


FIG. 143.

It was seen in Chapter VI that the current in the plate circuit for various values of plate and grid emf's., as represented by the static characteristic of the tube, may be expressed by the relation

$$I_p = a(E_p + kE_g)^m$$

where  $m$  was seen to be equal to 2 or  $\frac{3}{2}$ . If however only the straight central portion of the characteristic curve is considered, as is generally the case for amplification, or if the operation extends only over a small part of the curve, then  $m$  may be made equal to unity, and the equation becomes

$$I_p = a(E_p + kE_g) \quad (25)$$

and the internal plate resistance of the tube is

$$R = \frac{E_p + kE_g}{I_p} \quad (26)$$

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$e$ , produces synchronous variations of the plate current along the static characteristic curve of the tube corresponding to the plate voltage  $E_p$ . Thus, if the tube is operating at a plate potential of 200 volts, its characteristic curve will be the curve of Fig. 146 for a plate potential of 200 volts, and if the grid emf. is varied between  $-20$  and  $+20$  volts, the plate current will vary along the curve "200," from 3 to 67 milliamperes.

Suppose now, Fig. 145, that the plate circuit contains a resistance  $r$ . That is, to simplify the problem, suppose that the impedance  $Z$  of the external plate circuit is a resistance of value

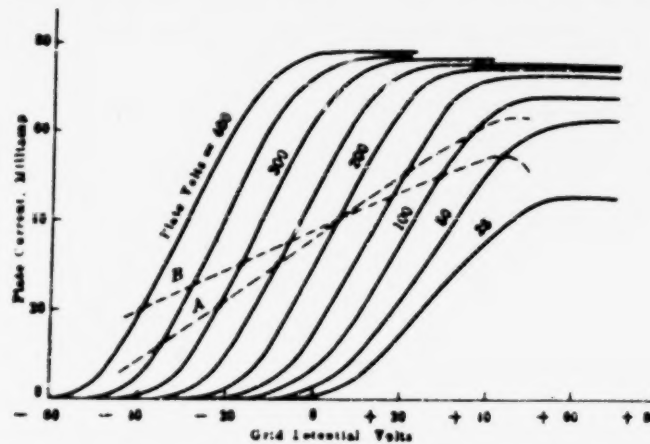


FIG. 146.

$r$ . The emf.  $E_b$  of the battery  $B$  is then equal to the potential drop  $rI_p$  along the resistance  $r$  plus that,  $I_p R = E_p$ , between the filament  $F$  and the plate  $P$  of the tube,  $I_p$  being the current flowing in the plate circuit. Thus,

$$E_b = E_p + rI_p$$

from which

$$E_p = E_b - rI_p \quad (30)$$

which expresses the difference of potential between the plate and filament of the tube.

If now the grid potential  $E_g$  is varied so as to increase the current  $I_p$  in the plate circuit, it is seen that the resistance drop  $rI_p$  in the external plate circuit will correspondingly increase. It then follows from equation (30) that, with the battery voltage  $E_b$  remaining constant, the plate potential  $E_p$  will de-

creases. Conversely, if the current  $I_p$  is decreased by decreasing the grid potential, the plate potential  $E_p$  will increase. Thus, on account of the external resistance of the plate circuit, the plate potential is no longer constant, but is a function of the plate current, and varies in opposite direction to the latter. In other words, the tube, operated under such conditions, has a *negative plate resistance reaction* as defined in connection with the oscillating arc, Chapter V. This will be taken up in greater detail in a later paragraph.

It follows from the above discussion, that when the external plate circuit has resistance and the grid potential is varied, the operating point of the tube no longer follows the static characteristic curve of the tube, which corresponds to a constant value of plate potential, but follows a different curve, called the *dynamic characteristic*. The shape of this characteristic curve depends on that of the static characteristic of the tube (and therefore on the tube construction and constants) and also on the resistance or impedance of the external plate circuit. This is shown in Fig. 146. The solid line curves are the static characteristic curves of the tube, while the dotted lines  $A$  and  $B$  represent the dynamic characteristics of the tube having an external plate circuit resistance of 5000 and 10,000 ohms, respectively. Thus, with an alternating grid potential and no resistance in the plate circuit, the tube follows the static characteristic curve corresponding to the potential  $E_b$  of the battery  $B$ . With an external plate circuit resistance of 5000 ohms, the operating point follows curve  $A$ , and with a resistance of 10,000 ohms, it follows curve  $B$ . Each of the curves  $A$  and  $B$  corresponds to a certain value of plate battery voltage. If this is changed, then the dynamic characteristic curve for a given external plate impedance will be shifted accordingly.

As expressed by the last equation, the greater the resistance  $r$  of the external plate circuit, or, more generally, the greater its impedance  $Z$ , the greater the variation of plate potential  $E_p$ , resulting from a given change of plate current  $I_p$ , brought about by a given variation of grid potential. This is shown in the curves of Fig. 146, where it may be seen that the slope of the dynamic characteristic curve decreases as the resistance (or impedance) of the external plate circuit is increased. As an extreme case, for infinite impedance, the curve would be parallel to the grid voltage axis of Fig. 146, showing that variations of grid

No. 727,331.

PATENTED MAY 5, 1903.

R. A. FESSENDEN.  
RECEIVER FOR ELECTROMAGNETIC WAVES.

APPLICATION FILED APR. 9, 1903

NO MODEL

2 SHEETS—SHEET 1.

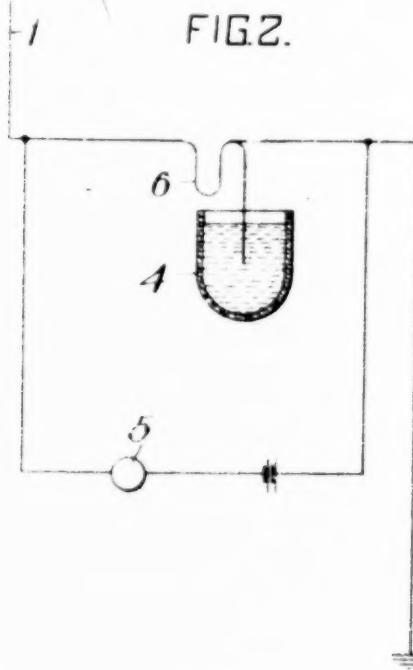
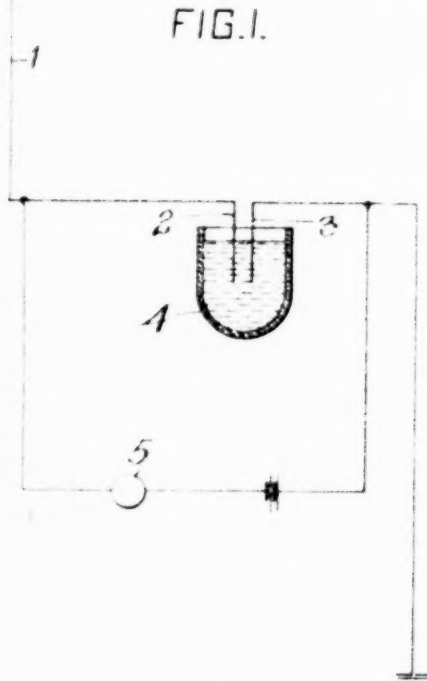
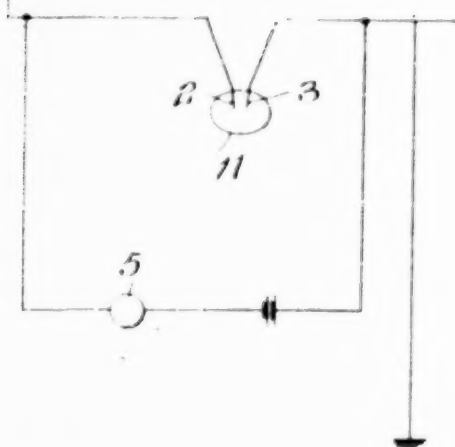


FIG. 3.



FIG. 4.



WITNESSES  
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*Frank A. Schuler*

INVENTOR  
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*by Dennis S. Wolcott* ATT'Y

No. 727,331

PATENTED MAY 5, 1903.

R. A. FESSENDEN.  
RECEIVER FOR ELECTROMAGNETIC WAVES.

APPLICATION FILED APR 9, 1903

NO. 727,331

2 SHEETS—SHEET 2

FIG. 5.



FIG. 6.

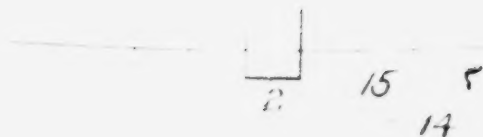


FIG. 7.

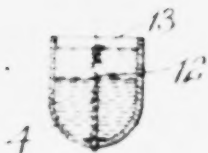


FIG. 8.



WITNESSES:

Robert Bradley  
Fred Kitchner

INVENTOR

Reginald A. Fessenden  
by Samuel B. Wilcott ATT'Y

Patented May 5, 1903.

## UNITED STATES PATENT OFFICE.

REGINALD A. TESSENIEN, OF PITTSBURG, PENNSYLVANIA.

## RECEIVER FOR ELECTROMAGNETIC WAVES.

SPECIFICATION forming part of Letters Patent No. 727,341, dated May 5, 1903.

To all whom it may concern: Be it remembered that I, REGINALD A. TESSENIEN, of the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in Receivers for Electromagnetic Waves, of which the following is a specification.

Be it known that I, REGINALD A. TESSENIEN, a citizen of the United States, residing at Pittsburgh, in the county of Allegheny and State of Pennsylvania, have invented or discovered certain new and useful Improvements in Receivers for Electromagnetic Waves, of which the following is a specification.

The invention described herein relates to certain improvements in current-actuated wave-responsive devices of the class or kind described and claimed in Letters Patent No. 727,341, granted to me August 12, 1902, and is adapted to be so affected by currents generated by electromagnetic waves as to produce a change in or variation of the conductivity of the receiving circuit, of which said device forms a part.

The invention is hereinafter more fully described and claimed.

In the accompanying drawings, forming a part of this specification, Figure 1 is a schematic diagram of a form of receiver embodying my invention. Figs. 2, 3, 4, and 5 are schematic views of modified forms of receiver. Fig. 6 is a diagrammatic view illustrating the mode of operation of the receiver. Figs. 7 and 8 illustrate further modifications of the construction of the receiver.

It is a primary feature of the hot-wire receiver described in the above patent referred to, and which has been termed a "barretter," that the amount of the electromagnetic waves is measured by a body of small mass, and which requires a small amount of energy to be affected to such an extent as to change its resistance and conductivity. Heretofore metals, especially platinum and silver, have been used in the construction of the barretter.

It has been found that substances other than metals are available for this purpose, and especially liquids, and of the latter class organic electrolytes have given even better commercial results than metals, for the following reasons: first, for the reason that they are not by reason of their nature inclined to excessive discharges; second, because the specific resistance of liquids is much greater, in some cases as much as a million times greater, than that of metals, and consequently to obtain the same resistance a

very much smaller mass, which is capable of being heated to a much larger extent, may be used; third, because the amount of change of resistance per degree of centigrade is very much greater—for example, the resistance of sulfuric acid when not quite concentrated changes approximately twelve per cent. per degree centigrade, while the change in platinum is only about one-third of one per cent. per degree centigrade. For all these reasons the results produced are very much greater and the action of the receiving device is much more reliable.

A liquid barretter or current-actuated wave-responsive device may be constructed in several ways. For instance, it is found that if the loop of a metal barretter such as described in the patent be broken while it is immersed in nitric acid it will nevertheless act even more efficiently than before, and hence a barretter may be formed consisting of two thin platinum wires 2 and 3, as shown in Fig. 1, having their ends immersed in a liquid contained in a suitable vessel 4 and forming, together with such liquid, a part of a receiving circuit, including an indicating device 5. This barretter may be connected either directly or indirectly with a receiving vertical line. A second method is to moisten a minute fiber—for example, a cotton thread—and to use it as the loop of a barretter. A desirable construction for this form of barretter is shown in Fig. 2 and consists of a fiber loop 6, having one end immersed in a liquid, which will be caused to travel along the fiber by capillary action and maintain the fiber in a saturated condition. A third method consists in forming a minute hole through a diaphragm 7, conveniently done by drawing down a very thin capillary tube to about three one thousandths (.003) of an inch internal diameter, cementing it into a hole in the center of a thick glass disk, and then grinding off the ends of the glass tube until they are flush with the surface of the diaphragm. The diaphragm is so arranged in a suitable vessel 4 as to form a partition between two portions of the solution in the cup or holder shown in Fig. 3, said portions being thus separated except by the thin column of the liquid contained in the capillary tube, said column forming the barretter. A ter-

5 terminal 9, preferably of platinum, connected  
 to the vertical, is immersed in one portion of  
 the liquid, and a second terminal 10, prefer-  
 ably of platinum also, is connected to ground  
 10 and has one end immersed in the other por-  
 tion of the liquid. These platinum wires,  
 with the liquid, are to be connected either di-  
 rectly in series with the vertical or in the  
 secondary of a transformer, and the barret-  
 15 ter thus formed is adapted to be used in the  
 manner described in prior patents granted to  
 me. A fourth method is to connect two  
 platinum wires by a thin film or small body  
 of conducting liquid, as indicated in Fig. 4.  
 20 This can be done conveniently by inserting  
 the wires into a bubble 11, formed of such  
 liquid. A fifth method is to insert a small  
 piece 12, of platinum or similar material,  
 into a liquid, such as nitric acid, so that only  
 25 its point is immersed. Fig. 5 shows such an  
 arrangement, the platinum wire being cov-  
 ered with silver. The silver wire has a di-  
 ameter of about .003 of an inch, and the  
 platinum core inclosed therein has a diam-  
 30 eter of about .00004 of an inch. The silver is  
 removed or eaten off from the lower extremity,  
 and the platinum core projects into the solu-  
 tion of nitric acid. This solution of nitric acid,  
 which preferably contains nitrous acid, is  
 35 covered by a layer of kerosene-oil, so as to  
 prevent evaporation of the acid and to pre-  
 vent the platinum from being fused. A sec-  
 ond platinum wire 13 is also immersed in  
 the liquid, preferably by inserting it through  
 40 the bottom of the vessel 4, and these wires  
 are connected to the vertical and to ground  
 and also included in the indicating-circuit.  
 It follows from the well-known electrical for-  
 mula giving the resistance of a cylindrical  
 45 body in a conducting medium that practi-  
 cally all the resistance is concentrated with-  
 in a short distance of the point where the  
 platinum wire 12 projects into the acid. For  
 example, if the platinum has a diameter of  
 50 .00004 of an inch, and it is immersed in the  
 acid to a depth of .00002 of an inch, practi-  
 cally all the temperature effected will take  
 place inside of a hemisphere of liquid whose  
 radius is .00004 of an inch. Such a hemi-  
 55 sphere is indicated in Fig. 6, where 2 rep-  
 resents the tip of the platinum, and 1 rep-  
 resents the hemisphere referred to. That this  
 is true will be seen by considering a second  
 hemispheric shell 14, having the thickness of  
 60 .00004 of an inch outside of the hemisphere 15.  
 The quantity of liquid in this shell 14 will be  
 more than eight times that in the shell 15,  
 and consequently it will take eight times the  
 amount of heat to raise it to this same extent.  
 65 At the same time the resistance of the shell  
 14 will be roughly the same as that of 15.  
 Hence it follows that the effect of the shell  
 14 will be only one eighth that of 15, and con-  
 sequently that although the effect of the dif-  
 ferent parts of the liquid within the bound-  
 ary of 15 does not vary much and all parts  
 are almost equally efficient, as soon as we

pass the boundary of 15 the effect of the vari-  
 ations of liquid beyond the boundary begins  
 to fall off very rapidly, and at a distance of 70  
 two or three times the diameter of the wire  
 it may be neglected. This may be deduced  
 at once from the proposition that the elec-  
 trical resistance between two copper disks  
 laid on a plate of sheet-copper is conditioned 75  
 almost entirely by the size of the disk, and by  
 the conductivity of the copper sheet; while  
 it is not affected except to an unappreciable  
 extent by the distance between them. As  
 shown in Fig. 7, the terminal 12 may be in- 80  
 serted through the bottom of the vessel 4, in  
 which case an indicating liquid, such as bi-  
 sulfid of carbon, having a greater specific  
 gravity than the nitric acid is used in con-  
 nection with the latter. As indicated in 85  
 Fig. 8, the wire 12 may be surrounded with  
 glass, so as to prevent any gas given off from  
 adhering to the wire, and thereby decreasing  
 its effective area.

The arrangement of circuits used with the 90  
 liquid barretter is practically the same as  
 that with the metal barretter described in the  
 patent referred to.

It is found that certain liquids act better  
 than others—as, for example, though carbon- 95  
 ate of soda, caustic soda, nitrate of potash,  
 and other substances give good results, it is  
 preferred to use nitric acid, for the reason  
 that the effects are stronger with it than with  
 most other liquids, and in the case of a burn- 100  
 out it is sufficient to screw down the plat-  
 inum wire until it is again immersed. The  
 burn-out is not liable to occur, on account of  
 the cooling effect of the liquid on the wire.  
 When using silver-coated platinum wire, the 105  
 screwing down of the wire into the nitric acid  
 will subject the silver to the action of the  
 acid, which will remove it from the platinum.  
 If, however, a high voltage—*e. g.*, seven or  
 eight—be used in the local circuit, carbonate 110  
 of soda will give larger effect than nitric acid.

It is to be noted that in the case of the  
 liquid barretter the action of the electromag-  
 netic waves is to cause a greater current to  
 pass in the local circuit, owing to the fact 115  
 that the conductivity of electrolytes increases  
 instead of decreases with heat. With a liq-  
 uid barretter having a resistance of between  
 six hundred and two thousand ohms the in-  
 crease of conductivity when the liquid is 120  
 heated is so marked as to permit of the opera-  
 tion of a siphon recorder or relay, though a  
 telephone may be used.

It is to be noted that there are several dis-  
 tinct methods in which metal and liquid can 125  
 be used in conjunction to form a receiver for  
 electromagnetic waves. First, the case of a  
 conductor, such as oxidized silver, in contact  
 with a liquid like mercury, where the action  
 is apparently a true coherer action caused by 130  
 the voltage produced by the electromagnetic  
 waves breaking down the insulating-oxid and  
 making a good electrical contact between the  
 silver and mercury. This effect does not oc-

on and is not utilized in my form of liquid barretter, for, in the first place, the resistance of the apparatus, if constant and definite, does not alter by shock or jar, returns to the same value no matter what the strength of the wave, and an entirely new piece of wire immersed to the same depth when a burn-out has occurred allows the same current to pass as any other similar piece of wire. Again, the increase of conductivity is always the same in amount under the same conditions and is exactly what calculations show should be produced by the heating of the liquid. Secondly, the change of resistance is exactly proportional to the energy of the electromagnetic waves, thus differing from the operation of the coherer. Third, if the size of the platinum wire be increased, the effect falls off very rapidly, as it should do according to theory, while in the case of coherer this is not true.

A second method of using liquid and metal is illustrated in Fig. 3 of Letters Patent No. 727,331, dated August 12, 1902, for rectifying the alternating currents produced by the electromagnetic waves. This effect does not occur when using my improved form of receiver, as may be readily shown by substituting such receiver for the electrolytic cell shown in the patent, in which case no such rectification will be found to occur. The evident reason for this is the fact that the resistance of the liquid barretter is so arranged as to absorb the energy and not to allow any of it to pass through. The energy by being absorbed none of it can be rectified. A second reason is that the polarization capacity of the barretter is too small to permit of such rectification. A third proof of this consists in the fact that the signals are obtained almost as well when both terminals consist of similar pieces of platinum, in which case, according to theory, there should be no rectification.

A third method consists in utilizing the depolarization of the electrode caused by the heating of the liquid. While there is no doubt that such an effect is probably produced, it is masked, and when in actual working practically the entire effect seems to be due to the change in resistance. An effect which appears when the voltage of the local circuit is raised to such a point as to cause the gases to bubble off from the point gives rise to a fourth method. When this is the case the waves effect an increase in resistance instead of diminution, possibly by first causing the bubble of gas to be deposited, which decreases the area of contact between the liquid and the platinum wire. This action is, however, irregular and occurs only

at a certain critical point, and as it does not always occur and regularly it is not available for actuating an indicating mechanism.

While the liquid receiver will work well no matter which pole is connected to the platinum, it is found in practice that better results are obtained when the platinum point is made negative, probably because bubbles of gas which may come off are dissolved in the liquid and tend to maintain the conductivity.

I claim herein as my invention—

1. A receiver for electromagnetic waves having a small heat capacity and consisting of a small quantity of liquid, substantially as set forth.

2. A receiver for electromagnetic waves consisting of a small quantity of liquid, the conductivity of which is affected by the action of electromagnetic waves, substantially as set forth.

3. A receiver for electromagnetic waves consisting of a small quantity of liquid adapted to have its resistance decreased by the action of electromagnetic waves, substantially as set forth.

4. A receiver for electromagnetic waves consisting of a material increaseable in conductivity by currents produced by electromagnetic waves, substantially as set forth.

5. A receiver for electromagnetic waves consisting of a liquid and rapidly responsive as regards temperature to effects produced by electromagnetic waves, substantially as set forth.

6. A receiver for electromagnetic waves consisting of a small quantity of nitric acid, substantially as set forth.

7. A receiver for electromagnetic waves, having in combination a small quantity of nitric acid, and terminals formed of platinum immersed in said liquid, substantially as set forth.

8. A receiver for electromagnetic waves having all its contacts perfect contacts and formed of a material increaseable in conductivity by currents produced by electromagnetic waves, substantially as set forth.

9. A receiver for electromagnetic waves, having in combination a small quantity of nitric acid, and terminals formed of platinum immersed in said liquid, the positive terminal having an external covering, substantially as set forth.

In testimony whereof I have hereunto set my hand.

REGINALD A. FESSENDEN.

Witnesses:

JESSIE E. BENT,

F. L. SCHLAFER.

## PLAINTIFF'S EXHIBIT 266

N. 780,842.

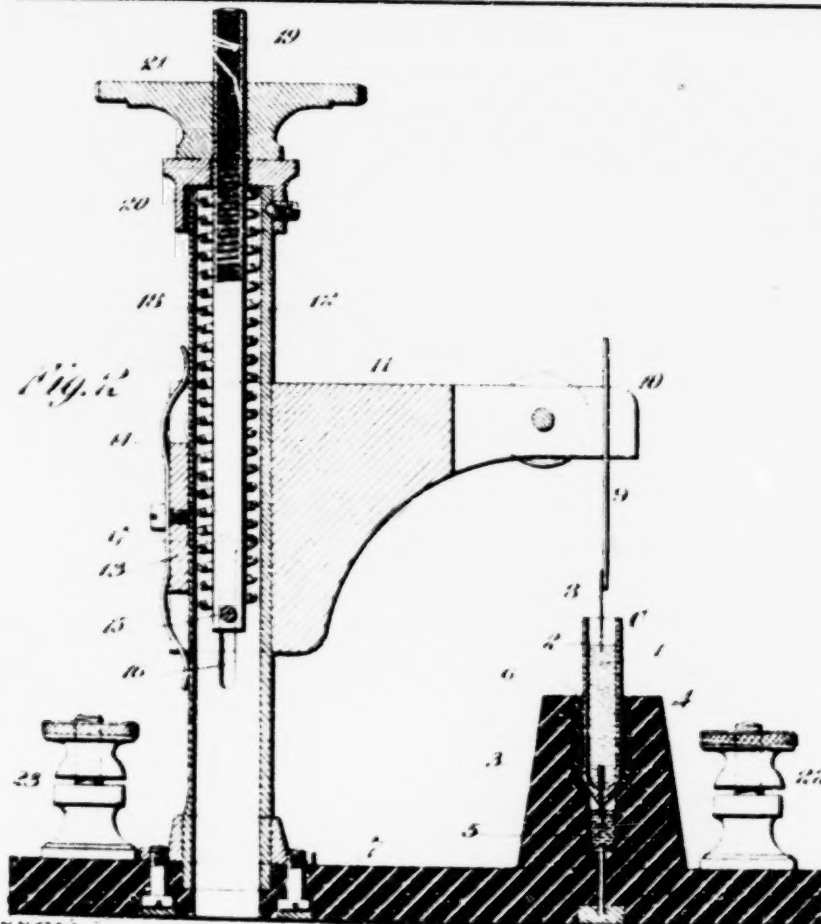
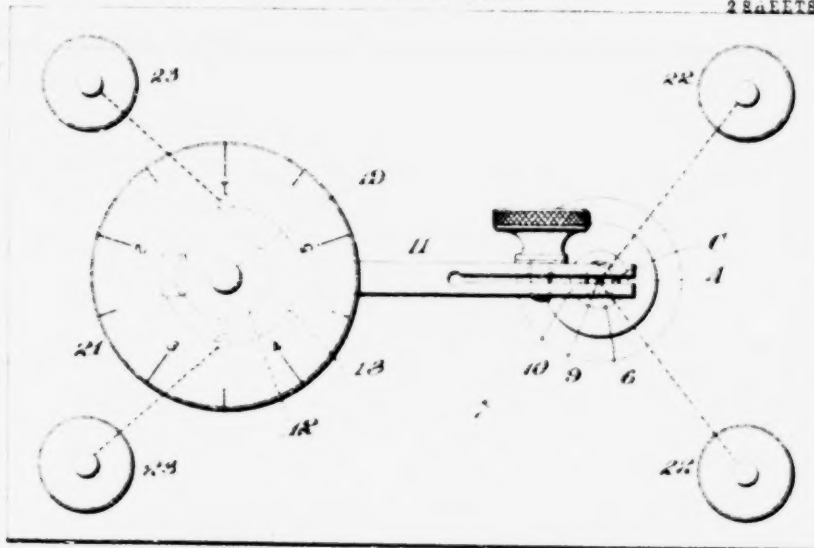
F. K. VREELAND.

PATENTED JAN. 24, 1905.

METHOD OF RECEIVING ELECTROMAGNETIC WAVES OR OTHER  
FEEBLE SIGNAL IMPULSES.

APPLICATION FILED AUG. 1, 1904.

284444-SHEET 1



Witnesses:

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Jas. A. Taylor

Inventor

F. K. Vreeland

Attorneys.

No. 780,842.

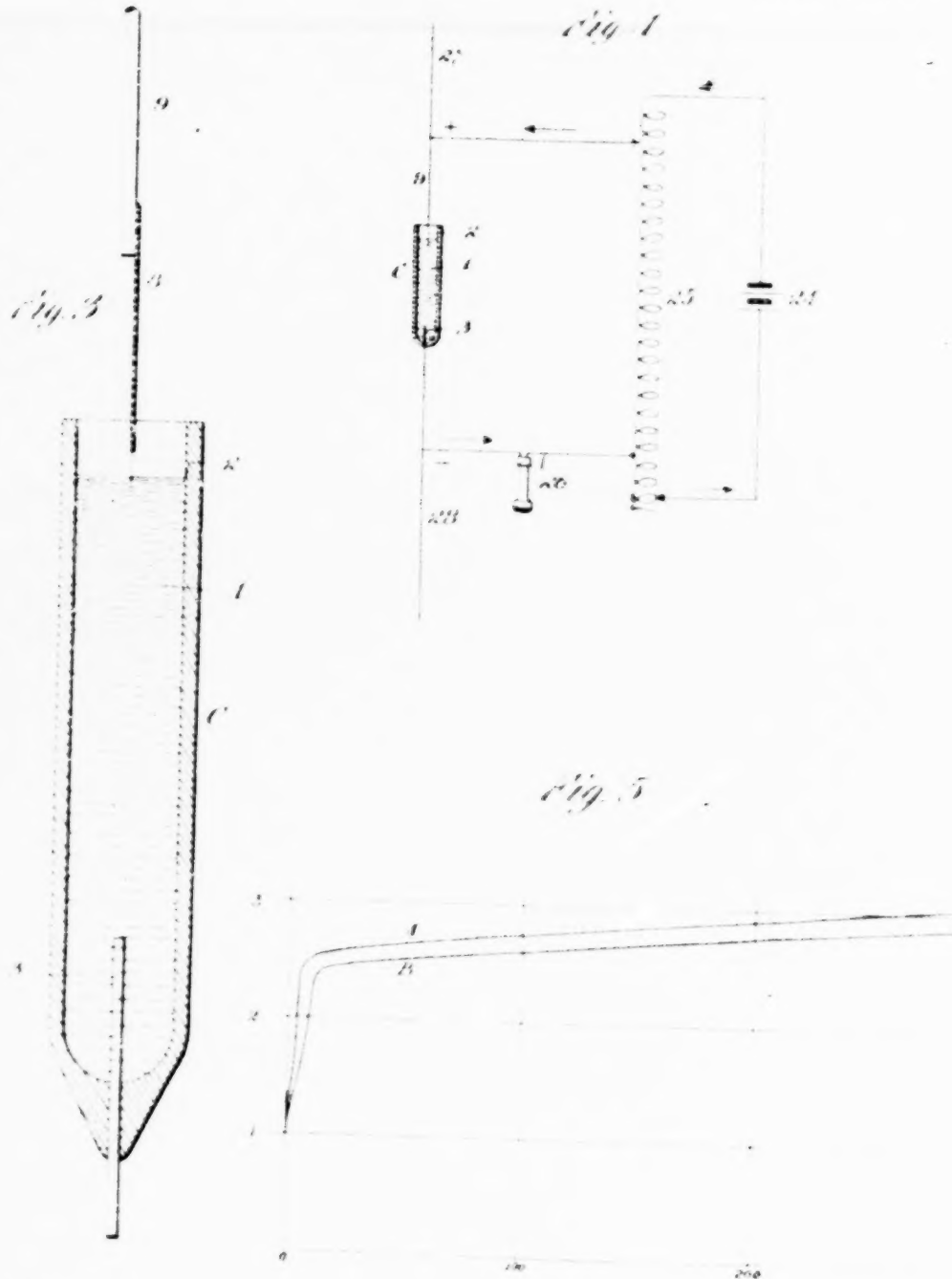
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FEIBLE SIGNAL IMPULSES.

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2 SHEETS-SHEET 1



Witnesses:

*Geo. F. Coleman*  
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Inventor

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*Wm. H. H. Taylor*

Attorneys.

## UNITED STATES PATENT OFFICE.

FREDERICK K. VREELAND, OF MONTCLAIR, NEW JERSEY, ASSIGNOR TO  
WIRELESS TELEGRAPH EXPLOITATION COMPANY, OF NEW YORK, N. Y.,  
A CORPORATION OF NEW YORK.

## METHOD OF RECEIVING ELECTROMAGNETIC WAVES OR OTHER FEEBLE SIGNAL IMPULSES.

SPECIFICATION forming part of Letters Patent No. 780,842, dated January 24, 1905.

Application filed August 1, 1904. Serial No. 219,013.

*To all whom it may concern:*

Be it known that I, FREDERICK K. VREELAND, a citizen of the United States, residing at Montclair, in the county of Essex and State of New Jersey, have invented a certain new and useful Method of Receiving Electromagnetic Waves or other Feeble Signal Impulses, of which the following is a description.

The object I have in view is the production of a method for the detection of electromagnetic waves or other feeble electrical signal impulses.

The invention has been found especially useful for the reception of signals in wireless telegraphy.

My invention depends upon the discovery made by me that an electrolytic cell of a special character when polarized to the proper critical point by a local battery is extremely sensitive to transitory or rapidly-oscillating currents from another source which when passed through it tend to depolarize the cell and cause it to offer less opposition to the passage of the local current, which rises and falls in value with the presence and absence of the transitory waves or impulses and affords an effective means for operating a telephone or other signal receiver. The polarized cell is one of special character, particularly in the respect that the anode of the cell (the electrode connected with the positive pole of the local battery) presents to the electrolyte a minute surface, producing a cell of minute electrolytic capacity. This I have found enables the cell to be depolarized sufficiently by electromagnetic waves or other feeble signal impulses to cause variations of the local current therethrough great enough to effectively operate a telephone or other signal receiver. The anode of the cell may be made of any suitable metal or other conducting material which is not changed by the electrolyte or attacked by the gaseous ions which are produced thereby. It may consist of a minute platinum wire having a diameter approximately .001 inch and immersed in the electrolyte a few thousandths of an inch. If the immersion is .001 of an inch, as it may be, the surface presented to the elec-

trolyte is approximately .001 square milli-  
meter. The size of this minute surface may  
be varied considerably in the region of this  
value. To obtain the best results, the area of  
contact-surface between the anode and the  
electrolyte should be properly proportioned  
to the intensity of the impulses to be detected.  
In general the apparatus becomes more sensi-  
tive to feeble impulses as the size of the anode  
is diminished; but when stronger impulses are  
received an increased effect may be obtained in  
the receiving instrument by increasing the  
area of the anode. For a given strength of  
impulse there is usually a certain size of anode  
which gives the maximum effect. If the anode  
be made larger than this, the apparatus be-  
comes less sensitive. If it be made smaller, the  
strength of the impulse is more than sufficient  
to effect the depolarization of the cell and the  
remaining energy is wasted. In practice,  
however, an anode small enough to be sensi-  
tive to the most feeble impulses to be received  
will usually work well with any stronger im-  
pulse. I have found that a platinum wire of  
.001 inch in diameter immersed in the elec-  
trolyte a few thousandths of an inch will meet  
this practical condition. This minute wire  
may be produced by drawing down a large  
silver wire with a platinum core, after which  
the end of the platinum core is exposed by  
dissolving the silver in nitric acid. As the  
useful action of polarization occurs at the  
anode, the size of the cathode is of little impor-  
tance, though it should be preferably much  
larger than the anode. I use ordinarily a cath-  
ode of platinum wire .01 inch in diameter sealed  
into the bottom of a small glass vessel and  
projecting into the electrolyte one-quarter of  
an inch. If the cathode be made as small as  
the anode, the device will still operate, but  
less efficiently owing to the increased resist-  
ance of the cell. The distance between the  
anode and the cathode is also immaterial ex-  
cept as it affects the resistance of the cell.  
Ordinarily I prefer to place them about one-  
half inch apart, though this distance may be de-  
creased to a few thousandths of an inch or in-  
creased to several inches without greatly af-  
fecting the result.

A suitable construction of cell is a vessel consisting of a glass tube having a bore a quarter of an inch in diameter and having a length of about an inch, one end of the tube being closed to form the bottom of the cell, and the cathodic being sealed by the fusion of the glass into this closed end of the tube. The anode may be supported by a piece of silver wire a half-inch in length and having the minute platinum core projecting from one end. The silver wire may be attached to a larger copper wire, which will be held by a vertically adjustable clamp, the anode projecting into the open upper end of the glass cell, which will be supported by a suitable socket. The electrolyte is preferably one with which the products of electrolysis are gaseous, particularly those generated at the anode. In order to use a solution which is decomposed into oxygen at the anode and hydrogen at the cathode. This is true of a large variety of substances, including the ordinary oxygen acids and alkali bases and their compounds, but many of these are not practically suitable on account of the disposition of solid matter upon the anode. Among the solutions that I have found suitable are sulfuric acid, nitric acid, sodium carbonate, potassium bichromate, potassium nitrate, and mercuric nitrate. All of these have the property of evolving oxygen gas at the anode when the latter is of platinum or other insoluble material. It is not necessary that the cathodic polarization electromotive force at the cathode is usually small even when hydrogen is evolved, whereas the polarization electromotive force due to the oxygen at the anode is much larger, and hence is relied upon to produce the useful effect of the apparatus. When the anode is in the form of a minute platinum wire supported by a pocket of other material, such as silver, it is desirable that the liquid electrolyte be a substance which will dissolve the pocket electrolytically, but will not attack it chemically. This makes it possible to renew the point when broken or otherwise injured by simply winding the covered wire down into the solution. The covering will be stripped off of the fine platinum core by electrolysis produced by the local battery and the covering is free from contact with the electrolyte. The covering, however, is not attacked chemically by the anode, which is supported by the wire, so as to leave the fine platinum point unsupported. With a silver covering, and thin wire, having outer coat and so long as the solution of an acid is sufficiently strong, it is preferable to use with the silver covering a twenty percent solution of sodium cyanide. A twenty percent solution of sodium cyanide, however, is attacked by the solution which is used, leaving the platinum point unprotected, and if the solution is greatly de-

minished in strength, the operation of the cell is impaired by the formation of insoluble cyanide anode. When such a cell is made, it gives a source of sufficient electromotive force, so as to permit of using the cell with the positive pole of the battery connected to the minute anode, the cell, as a source of polarization, reverses a current of the anode, which opposes the flow of the current from the battery. This counter action of the anode is due mainly to the presence of the cyanide, which is evolved at the anode. The balance between the current of the impressed electromotive force with a cell of this character and having an electrolyte containing about twenty percent sodium cyanide is illustrated in Fig. 6. The ordinates represent a varying electromotive force applied to the cell by the local battery expressed in volts, while the abscissas represent the current flowing through the cell expressed in milliamperes of an ampere. The upper curve, A, shows the relation between the current and the impressed electromotive force of the cell in its normal condition, the polarization being entirely due to the current from the local battery. The lower curve, B, represents the same relation when the cell is reversed by oscillating currents, such as are used in wireless telegraphy. Theoretically, the decomposition voltage is about 1.7 volts when the products of electrolysis are oxygen and hydrogen, but according as currents from the curve A, it is found that a small current may flow even at impressing voltages as low as one or 1.4 volts. This current, which is very minute, is probably due to the solution of the gases through the liquid and not to true conduction. On the other hand, it is found that the polarization voltage increases with the strength of the polarizing current. Thus, as appears from curve A, the current increases gradually with increasing impressed voltage up to about 2.4 volts, at which point the polarization voltage approaches a maximum, and on the upper part of the curve the impressed current is governed practically by the internal resistance of the cell. Throughout the curve that part of the curve there is a constant evolution of gas bubbles in the cell, which indicates the effectiveness of the apparatus. A certain constant current appears to be necessary to maintain the polarization at a steady value, which balances the impressed electromotive force. A slight sudden increase in the impressed electromotive force results in a large rush of current, which, however, diminishes rapidly as the polarization readjusts itself to the increase in electromotive force. A similar effect is noted well when electrical oscillations or other than direct currents are passed through the cell. I observe the effect of completely and partially depolarizing the cell, and a corresponding increase of the local current results. The curve B in Fig. 6 illustrates this. At two volts, for instance, the local current is 35

creases under the influence of the oscillations from .000003 to .000009 of an ampere. These are the steady values of the current. The momentary increase while the cell is readjusting itself to the changed conditions is very much greater and being of a sudden and transitory character has a much larger effect upon a telephone connected in the circuit than would be indicated by the values derived from the curve. For these reasons the apparatus is most sensitive when used with a telephone for receiving audible signals; but the constant increase of current indicated by the curve may also be utilized to operate a siphon-recorder or other recording apparatus. The terminal voltage of the cell produced by the local battery at which the cell is most sensitive to electromagnetic waves or other feeble impulses varies with different electrolytes and with different strengths of the solution. The cell is sensitive to oscillations over a considerable range of electromotive force; but it works most efficiently at a point a little below the bend of the curve, where a decided evolution of gas begins to occur. At this point the cell is less stable than at other voltages, and any stimulus gives a greater change in the state of polarization, and hence in the local current. This best voltage is about 1.8 volts for strong nitric acid, is higher for dilute acid, and may reach four or five volts or more in dilute alkali solutions. Where the feeble impulses to be detected are unidirectional, care should be taken that they are passed through the cell in a direction opposite to the flow of the current from the local battery. These impulses will then have the effect of momentarily diminishing or even entirely annulling the existing polarization, resulting in the flow of a largely-increased current from the local battery through the depolarized cell. The apparatus is thus useful for detecting the feeble and transitory currents employed in cable telegraphy or for similar uses. If the polarity of the local battery is reversed—i.e., its negative pole is connected to the electrode of minute surface—the apparatus becomes inoperative for the detection of electromagnetic waves or other feeble signal impulses. In this case the large terminal becomes the anode and the currents to be detected are too feeble to effect any appreciable change of polarization over its large surface. The apparatus will work with a voltage of the local battery considerably below the decomposition voltage of the cell, especially when the impulses to be detected are strong; but under these conditions the apparatus is less sensitive. It produces, however, to produce by the local battery a difference of potential at the terminals of the cell somewhat higher than the decomposition voltage of the cell, but below the point where violent evolution of gas is caused.

My detector of electromagnetic waves, the method of operation of which and whose prin-

cipal constructional features have already been described, possesses numerous advantages over apparatus heretofore employed for the same purpose. It is extremely sensitive and responds to the most rapid impulses, being practically instantaneous in action. It is reliable and permanent in adjustment, does not require delicate handling or adjustment in operation, is not injured by lightning discharges or by the transmitting apparatus, lends itself readily to tuning for selective signaling—is capable of being used either for the production of audible signals by a telephone or for the recording of signals, and, finally, it is characterized by extreme simplicity of construction.

In the drawings, Figure 1 is a top view of the cell-support and its constructional adjuncts. Fig. 2 is a vertical section of the apparatus of Fig. 1, the size of the minute anode being necessarily exaggerated. Fig. 3 is an enlarged view of the cell. Fig. 4 is a diagram illustrating the connections of the cell for receiving electromagnetic waves, and Fig. 5 represents curves illustrating the action of the cell.

The cell C is a small glass vessel containing the electrolyte 1, into which dips the minute anode 2. The cathode 3 of larger area is scaled into the glass bottom of the vessel C, projecting inwardly into the electrolyte and outwardly beyond the bottom of the vessel. The cell C is removably mounted in a socket 4, terminating in a mercury-cup 5, into which the outer end of the cathode 3 projects for making connection with the cathode. A bushing 6, of soft-rubber tubing, is inserted in the socket 4 to make a tight fit with the glass cell, so as to hold it firmly in place and prevent spilling of the mercury. The socket 4 is mounted upon a base 7, both the socket and base being preferably of a material not affected by the electrolyte. The minute anode 2 is supported by a silver jacket 8, which is attached to a copper wire 9, held by a screw-clip 10 on the end of a horizontal arm 11. This arm is mounted upon a standard 12 on the base 7 by a long sleeve 13. Springs 14, attached to the arm 11, bear against the flat face of the standard 12, so as to take up lost motion. The arm 11 is guided in its movement on the standard 12 by a pin 15, working in slots 16, the upper ends of these vertical slots 16 being extended into lateral slots 17, so as to permit the arm 11 to be swung to one side when moved to its uppermost position and after the anode is clear of the cell. The standard 12 is hollow, and within it is placed a spiral spring 18, pressing downwardly on the cross-pin 15 and surrounding a screw 19, which extends upwardly from the standard 12. The cap 20 confines the spring 18, which spring exerts a downward pressure on the cross-pin 15, tending to keep the arm

11 in its lowermost position. The arm 11 is fitted by means of a nut 21 turning upon the screw 10 and bearing upon the cap 20. The top of the nut 21 may be graduated to show the degree of adjustment. Binding posts 22 are connected with the mercury-cup 5 and through it with the cathode of the cell, while binding posts 24 are connected with the stand 12 and through it with the anode of the cell.

Referring to Fig. 4, which shows the connections of the apparatus for use as a receiver in wireless telegraphy, 24 is the local battery, having its positive pole connected to the anode of the cell and its negative pole connected to the cathode. 25 is an adjustable resistance-coil or potentiometer connected in shunt to the battery and cell, whose function is to regulate the voltage across the terminals of the cell. This coil is wound inductively to prevent the escape of the oscillations through itself or through the battery, a sufficient length of the coil for this purpose being always maintained in circuit between the battery and the cell. 26 is a telephone-receiver which is connected in the battery circuit between the potentiometer and the cell. 27 is the antenna or aerial wire, and 28 is the ground-wire, which are connected, respectively, with the anode and cathode of the cell, but may have reverse connections with the cell.

The operation of the apparatus is evident from the description already given.

The apparatus described is not claimed herein, but will be made the subject of a divisional application.

What I claim is:

1. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing an electrolytic cell of minute electrolytic capacity, effecting by such waves or impulses a partial or complete depolarization of such cell, and observing increases in current caused by the depolarization of the cell by said waves or impulses.

2. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing an electrolytic cell having a minute anode, effecting by such waves or impulses a partial or complete depolarization of such cell, and observing increases in current caused by the depolarization of the cell by said waves or impulses.

3. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing an electrolytic cell having a minute anode at which gas is evolved, effecting by such waves or impulses a partial or complete depolarization of such cell, and observing increases in current caused by the depolarization of the cell by said waves or impulses.

4. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing an electrolytic cell hav-

ing a minute anode at which oxygen is evolved, effecting by such waves or impulses a partial or complete depolarization of such cell, and observing increases in current caused by the depolarization of the cell by said waves or impulses.

5. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing by a local source of electromotive force an electrolytic cell, passing the waves or impulses to be detected through said cell in such manner as to wholly or partially depolarize the cell and thereby increase the current in the local circuit, and observing the variations in flow of the local current.

6. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing by a local source of electromotive force an electrolytic cell having a minute anode, passing the waves or impulses to be detected through said cell in such manner as to wholly or partially depolarize the cell and thereby increase the current in the local circuit, and observing the variations in flow of the local current.

7. The method of detecting electromagnetic waves or other feeble signal impulses, which consists in polarizing by a local source of electromotive force an electrolytic cell, passing the waves or impulses to be detected through said cell in parallel with the polarizing current, and observing the variations in flow of the local current.

8. The method of detecting electromagnetic waves or other feeble signal impulses, which consists in polarizing by a local source of electromotive force an electrolytic cell having a minute anode, passing the waves or impulses to be detected through said cell in parallel with the polarizing current, and observing the variations in flow of the local current.

9. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing an electrolytic cell by an impressed voltage higher than the decomposition voltage of the cell but lower than the voltage at which a violent evolution of gas is caused, effecting by such waves or impulses a partial or complete depolarization of such cell, and observing changes in the polarization of the cell caused by said waves or impulses.

10. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing an electrolytic cell having a minute anode by an impressed voltage higher than the decomposition voltage of the cell but lower than the voltage at which a violent evolution of gas is caused, effecting by such waves or impulses a partial or complete depolarization of such cell, and observing changes in the polarization of the cell caused by said waves or impulses.

11. The method of detecting electromagnetic waves or other feeble electrical impulses, which

consists in polarizing an electrolytic cell by means of a local source of electromotive force producing at the cell a voltage above the decomposition voltage of the cell but below the point where a violent evolution of gas is caused, passing the waves or impulses to be detected through said cell and thereby wholly or partially depolarizing the same whereby the current in the local circuit will be increased, and observing the variations in flow of the local current.

12. The method of detecting electromagnetic waves or other feeble electrical impulses, which consists in polarizing an electrolytic cell having a minute anode by means of a local source

of electromotive force producing at the cell a voltage above the decomposition voltage of the cell but below the point where a violent evolution of gas is caused, passing the waves or impulses to be detected through said cell and thereby wholly or partially depolarizing the same whereby the current in the local circuit will be increased, and observing the variations in flow of the local current.

This specification signed and witnessed this 28th day of July, 1904.

FREDERICK K. VREELAND.

Witnesses

JNO. R. R. TAYLOR

JOHN L. LOESCH.

Corrections in Letters Patent No. 780,842

It is hereby certified that in Letters Patent No. 780,842, granted January 24, 1905 upon the application of Frederick K. Vreeland, of Montclair, New Jersey, for an improvement in "Methods of Receiving Electromagnetic Waves or other Feeble Signal Impulses," errors appear in the printed specification requiring correction, as follows: In line 25, page 2, the word "disposition" should read *deposition*; and in line 54, same page, the comma after the word "liquids" should be stricken out; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of March, A. D., 1905.

[SEAL]

F. I. ALLEN,

Commissioner of Patents.

[fol. 2716]

## PLAINTIFF'S EXHIBIT 268

II. "On Electric Discharge between Electrodes at different Temperatures in Air and in High Vacua." By J. A. Fleming, M. A., D.Sc., Professor of Electrical Engineering in University College, London. Communicated by Professor G. C. Foster, F.R.S. Received December 16, 1889.

## (Preliminary Notice)

It has been known for some time that if a platinum plate or wire is sealed through the glass bulb of an ordinary carbon filament incandescent lamp, this metallic plate being [fol. 2717] quite out of contact with the carbon conductor, a sensitive galvanometer connected between —s insulated metal plate enclosed in the vacuum and the external *positive* electrode of the lamp indicates a current of some milli-amperes passing through it when the lamp is set in action, but the same instrument when connected between the *negative* electrode of the lamp and the insulated metal plate indicates no sensible current. This phenomenon in carbon incandescence lamps was first observed by Mr. Edison, in 1884, and further examined by Mr. W. H. Preece, in 1885.\*

\* See 'Roy. Soc. Proc.,' vol. 38, 1885, p. 219. "On a Peculiar Behaviour of Glow Lamps when raised to High Incandescence."—In this paper Mr. Preece describes a very careful series of observations carried out with Edison incandescence lamps, and which cover the same ground as a portion of the experiments here described. The results given in (4), (7), and (11) confirm the facts which were first ascertained by him. He also arrived at the general conclusion that the phenomena so observed are due to an electric convection by matter projected from the incandescent carbon. By carrying up the working electromotive force of the lamp to a point productive of very high incandescence, he was able to measure the resulting current through a galvanometer connected between the positive lamp electrode and the middle plate corresponding to every degree of incandescence, and showed that, whilst increasing up to a certain point, the galvanometer current fell off rapidly soon after a certain critical temperature was reached, which corresponded to the appearance of a blue light or haze in the glass receiver.—[Jan. 14th, 1890.]

The primary object of the experiments described in this paper was the further examination of this effect, but the inquiry has extended itself beyond this range and embraced some general phenomena of electric discharge between electrodes at unequal temperatures, and in particular has revealed some curious effects in the behaviour of an electric arc taken between carbon poles towards a third insulated carbon or metal poles.

The first series of experiments had reference to the nature of the effect observed in the incandescence lamps having an insulated wire or plate placed in the vacuum.

If a platinum wire is sealed through the glass bulb of an ordinary carbon filament lamp and carries at its extremity a metal plate, so placed as to stand up between the legs of the carbon horseshoe without touching either of them, then when the lamp is actuated by a continuous current it is found that:

(1.) This insulated metal plate is brought down instantly to the potential of the base of the negative leg of the carbon, and no sensible potential difference exists between the insulated metal plate and the negative electrode of the lamps, whether the test be made by a galvanometer, by an electrostatic voltmeter, or by a condenser.

(2.) The potential difference of the plate and the positive electrode of the lamp is exactly the same as the working potential difference of the lamp electrodes, provided this is measured electrostatically, *i.e.*, by a condenser, or by an electrostatic voltmeter taking no current, but if measured [fol. 2718] by a galvanometer the potential difference of the plate and the positive electrodes of the lamp is something less than that of the working lamp electrodes.

(3.) This absolute equality of potential between the negative electrode of the lamp and the insulated plate only exists when the carbon filament is in a state of vivid incandescence, and when the insulated plate is not more than an inch or so from the base of the negative leg. When the lamp is at intermediate stages of incandescence, or the plate is considerably removed from the base of the negative leg, then the plate is not brought down quite to the same potential as the negative electrode.

(4.) A galvanometer connected between the insulated plate and the *positive* electrode of the lamp shows a current

increasing from zero to four or five milliamperes, as the carbon is raised to its state of commercial incandescence. There is not any current greater than 0.0001 of a milliamperè between the plate and *negative* electrode when the lamp has a good vacuum.

(5.) If the lamp has a bad vacuum this inequality is destroyed, and a sensitive galvanometer shews a current flowing through it when connected between the middle plate and either the positive *or* negative electrode.

(6.) When the lamp is actuated by an *alternating* current a *continuous* current is found flowing through a galvanometer, connected between the insulated plate and *either* terminal of the lamp. The direction of the current through the galvanometer is such as to show that negative electricity is flowing from the plate through the galvanometer to the lamp terminal. This is also the case in (4); but, if the lamp has a bad vacuum, then negative electricity flows *from* the plate through the galvanometer *to* the positive terminal of the lamp, and negative electricity flows *to* the plate through the galvanometer from the negative terminal of the lamp.

(7.) The same effects exist on a reduced scale when the incandescent conductor is a platinum wire instead of carbon filament. The platinum wire has to be brought up very near to its point of fusion, in order to detect the effect, but it is found that a current flows between the positive electrode of a platinum wire lamp and a platinum plate placed in the vacuum near to the negative end of that wire.

(8.) The material of which the plate is made is without influence. Platinum, aluminium, and carbon have been indifferently employed.

(9.) The active agent in producing this effect is the *negative* leg of the carbon. If the negative-leg of the carbon is covered up by enclosing it in a glass tube this procedure entirely, or nearly entirely, prevents the production of a current in a galvanometer connected between the middle plate and the positive terminal of the lamp.

(10.) It is a matter of indifference whether a glass or [fol. 2719] metal tube is employed to cover up the negative leg of the carbon; in any case this shielding destroys the effect.

(11.) If, instead of shielding the negative leg of the carbon, a mica screen is interposed between the negative leg and the side of the middle plate which faces it, then the

current produced in a galvanometer connected between the positive terminal of the lamp and the middle plate is much reduced. Hardly any effect under the same circumstances is produced when the mica screen is interposed on that side of the metal plate which faces the positive leg of the carbon.

(12.) The position of the metal plate has a great influence on the magnitude of the current traversing a galvanometer connected between the metal plate and the positive terminal of the lamp. The current is greatest when the insulated metal plate is as near as possible to the base of the negative leg of the carbon, and greatest of all when it is formed into a cylinder which embraces without touching the base of the negative leg.

The current becomes very small when the insulated metal plate is removed to 4 or 5 inches from the negative leg, and becomes practically zero when the metal plate is at the end of a tube forming part of the bulb, which tube has a bend at right angles in it. Copious experiments have been made with metal plates in all kinds of positions.

(13.) The galvanometer current is greatly influenced by the surface of the metal plate, being greatly reduced when the surface of the plate is made small, or when the plate is set edgewise to the negative leg, so as to present a very small apparent surface when seen from the negative leg. In a lamp having the usual commercial vacuum, the effect is extremely small when the insulated metal plate is placed at a distance of 18 inches from the negative leg, but even then it is just sensible to a very sensitive galvanometer.

(14.) If a charged condenser has one plate connected to the insulated metal plate, and the other plate connected to any point of the circuit of the incandescent filament, this condenser is instantly discharged if the positively charged side of the condenser is connected to the insulated plate, and the negative side to the hot filament. If, however, the negative leg of the carbon horseshoe is shielded by a glass tube, this discharging power is much reduced, or altogether removed.

(15.) If the middle plate consists of a separate carbon loop, which can itself be made incandescent by a separate insulated battery, then, when this middle carbon is rendered incandescent and employed as the metal plate in the above experiment, the condenser is discharged when the nega-

tively charged side of it is connected to the hot middle carbon, the positively charged side of it being in connexion with the principal carbon horseshoe.

[fol. 2720] (16.) If this last form of lamp is employed as in (4) the subsidiary carbon loop being used as a middle plate, and a galvanometer being connected between it and either the positive or negative main terminal of the lamp, then when the subsidiary carbon loop is cold, we get a current through the galvanometer only when it is in connexion with the positive main terminal of the lamp, but when the subsidiary carbon is made incandescent by a separate insulated battery, we get a current through the galvanometer when it is connected either to the positive *or* to the negative terminal of the lamp. In the first case the current through the galvanometer is a negative current, flowing from the middle carbon to the positive main terminal, and in the second case it is a negative current, from the negative main terminal to the middle subsidiary hot carbon.

(17.) If a lamp having a metal middle plate held between the legs of the carbon loop has a galvanometer connected between the negative main terminal of the lamp and this middle plate, we find that when the carbon is incandescent there is no sensible current flowing through the galvanometer. The vacuum space between the middle plate and the hot negative leg of the carbon possesses, however, a curious unilateral conductivity. If a single Clark cell is inserted in series with the galvanometer, we find that this cell can send a current deflecting the galvanometer when its negative pole is in connexion with the negative main terminal of the lamp, but if its positive pole is in connexion with the negative terminal of the lamp, then no current flows. The cell is thus able to force a current through the vacuum space when the direction of the cell is such as to cause negative electricity to flow across the vacuum space from the hot carbon to the cooler metal plate, but not in the reverse direction.

(18.) If a vacuum tube is constructed, having at each end horseshoe carbon filaments sealed into it, and which can each be made separately incandescent by an insulated battery, we find that such a vacuum tube, though requiring an electromotive force of many thousands of volts to force a current through it when the carbon loops are used as elec-

trodes and are *cold*, will yet pass the current from a single Clark cell when the carbon loop which forms the negative electrode is rendered incandescent. It is thus found that a high vacuum terminated electrically by unequally heated carbon electrodes possesses an unilateral conductivity, and that electric discharge takes place freely through it under an electromotive force of a few volts when the *negative* electrode is made highly incandescent.

(19.) These experimental results above described led the writer to investigate, in the same manner, the electric arc between carbon poles taken in air. If an electric arc is formed, in the usual way, between carbon poles, and a third insulated carbon pole is allowed to dip into or touch the electric arc, or, better still, has the electric arc projected against [fol. 2721] it by a magnet, it is found that this third or insulated pole is brought down almost to the potential of the negative carbon of the arc, and that a galvanometer connected between the third insulated carbon and the negative carbon of the arc indicates no current, but that if joined up between the positive carbon and the middle carbon a strong current of about an ampère or so is found to be passing. If an electric bell or an incandescent lamp is joined up between the third carbon and the *negative* carbon of the arc, they do not work; but if the bell or the lamp is joined between the *positive* carbon of the arc and the third carbon, they are set in action by a strong current passing through them. These effects are produced, although the third carbon (which is best held at right angles to the other two forming the arc) is half or three quarters of an inch away from the positive and negative carbon, the sole condition being that the flame of the arc must touch or be projected by a magnet so as to touch this third carbon. We have, therefore, similar phenomena in the case of the arc and incandescence lamps.

(20.) When the electric arc is being projected against the third carbon, and has brought it down to the same potential, a galvanometer joined in between the two carbons shows no current; but this space between the negative carbon of the arc and the third carbon possesses a unilateral conductivity, and will pass the current from a small battery of secondary cells one way, but not the other. The secondary battery when joined in series with the galvanometer sends a current, if its negative pole is in connexion with the negative carbon of the arc, and its positive pole, through the

galvanometer, with the third carbon; but if the secondary battery is reversed in position it sends no current. Negative electricity can pass along the flame-like projection of the arc *from* the hot negative carbon *to* the cooler third carbon, but not in an opposite direction.

(21.) If the arc is projected by means of a magnet for a long time against the third insulated carbon, it *craters* it out in the same fashion as the crater of the positive carbon, and the tip of this third carbon, where it has received the flame-like blast of the arc, is converted into graphite.

The same effects are observed if an iron rod is used as a third pole, and in this case the end is converted into *steel*, and rendered so hard as to be scarcely touched by the file when it has been quenched in water.

In seeking for an hypothesis to connect together these observed facts, the one which suggests itself as most in accordance with the facts is as follows:—

In the case of a carbon incandescence lamp when at vivid incandescence, carbon particles are being projected from all parts of the filament, but chiefly from the negative half of [fol. 2722] the loop. These carbon molecules carry *negative* charges of electricity, and when they impinge upon a metal plate placed in the vacuum they can discharge themselves if this plate is positively electrified, either by being in metallic connexion with the positive electrode of the lamp or with a separate positively charged body. When the plate is simply insulated the stream of negatively charged carbon molecules brings down this insulated plate to the potential of the base of the negative leg, or to the potential of that part of the carbon conductor from which it is receiving projected molecules. These carbon molecules projected from an incandescent conductor can carry negative charges, but either cannot be positively charged, or else lose a positive charge almost instantly when projected off from the conductor.

In the case of the electric arc we must suppose that the negative carbon is projecting off a torrent of negatively electrified carbon molecules, and these, impinging against the positive carbon, wear out a crater in it by a sand-blast-like action.

The higher temperature of the positive carbon in a continuous current arc is thus explained as due to the impact of the carbon molecules projected from the negative carbon.

If the electric arc is diverted against a third insulated lateral carbon, the carbon blast from the negative carbon wears out a crater in it and brings it down to the same potential as itself. The actions going on in an electric arc may be considered to be somewhat as follows:—When the carbons are first put together, the resistance at the point of contact renders the extremities incandescent. When thus incandescent and separated, the electrification of each carbon is sufficient to begin the projection of molecules from both positive and negative carbons, probably most largely from the latter. The impact of the molecular stream from the negative pole raises the temperature of the positive carbon, and this again by radiation raises the temperature of the negative carbon end. The electromotive force is thus able to keep up a projection of negatively charged carbon molecules from the end of the negative carbon, which molecules are loosened from the mass by heat, and then move away by electric repulsion from the surface in virtue of the electric charge which they retain. It would seem as if a hot carbon molecule cannot retain a positive charge, and hence the potential difference between a third insulated carbon and the positive carbon of the arc is nearly the same as the potential difference of the positive and negative carbons of the arc. The rise of potential along the arc takes place very suddenly just in the neighbourhood of the crater of the positive carbon.

It has often been suggested that the electric arc contains a counter electromotive force. It is questionable whether such experiments as those of Edlund (*Phil. Mag.*, vol. 36, 1868, p. 352) are entirely conclusive on this point.

[fol. 2723] It has been shown by other experimenters \* that for arcs of varying length, but the same current, beyond a certain small initial length, the potential difference necessary to maintain the arc is proportional to the length of the arc plus a constant. This might thus be interpreted to mean that a certain proportion of the work-electromotive force of the arc was employed in detaching the carbon molecules from the mass of the poles, and that the excess alone is represented by the current produced in an arc of definite length.

\* See Professors Ayrton and Perry, "Proceedings of the Physical Society," vol. 5, p. 201.

In the case of the incandescence lamps the hypothesis of the projection of negatively charged carbon molecules from the incandescent conductor, to which the name of *molecular electroraction* may be given, will suffice to explain all the various different effects produced by varying the surface, position, and distance of the metal plate against which they impinge, and also the nullifying effect of shielding this plate from the negative leg of the carbon.

That this molecular discharge goes on chiefly from the negative leg is additionally proved by the greater erosion which takes place in the deposit of carbon on the negative leg when the carbon is uniform and traversed by a continuous current.

The hypothesis that a carbon molecule detached from an incandescent carbon surface in a high vacuum can only convey away a negative charge, reconciles also the above described observed effects in which a negative discharge can be made *out* of a hot surface of carbon more easily than a positive discharge. When an electromotive force is applied to two metallic terminal or electrodes sealed into a good vacuum, it is well known that a certain initial electromotive force has to be applied before any electric current begins to flow through the gas at all. It seems conclusively proved by Mr. Crookes's researches that the nature of an electric discharge through a high vacuum consists in a torrent of electrified particles proceeding from the negative electrode. If this is the case the initial electromotive force required to begin a discharge through such rarefied gas would naturally be reduced by heating the negative electrode, so as to favour and assist the detachment of the charged molecules of that electrode. The effect of heating the negative electrode in facilitating discharge through vacuum spaces has previously been described by W. Hittorf ('Annalen der Physik und Chemie,' vol. 21, 1884, p. 90-139), and it is abundantly confirmed by the above experiments. We may say that a vacuum space bounded by two electrodes—one incandescent, and the other cold—possesses a unilateral conductivity for electric discharge when these electrodes are within a distance of the mean free path of projection of the molecules which the impressed electromotive [fol. 2724] force can detach and send off from the hot negative electrode.

This unilateral conductivity of vacuum spaces having unequally heated electrodes has been examined by MM. Elster and Geitel (see 'Wiedemann's Annalen,' vol. 38, 1889, p. 40), and also by Goldstein ('Wied. Ann.,' vol. 24, 1885, p. 83), who in experiments of various kinds have demonstrated that when an electric discharge across a vacuum space takes place from a carbon conductor to another electrode, the discharge takes place at lower electromotive force when the carbon conductor is the negative electrode and is rendered incandescent.

[fol. 2725]

PLAINTIFF'S EXHIBIT 269

"On the Conversion of Electric Oscillations into Continuous Currents by means of a Vacuum Valve." By J. A. Fleming, M.A., D.Sc., F.R.S., Professor of Electrical Engineering in University College, London. Received January 24. — Read February 9, 1905.

An electric oscillation being an alternating current of very high frequency, cannot directly affect an ordinary movable coil or movable needle galvanometer.

Appliances generally used for detecting electric waves or electric oscillations are, therefore, in fact, alternating current instruments, and must depend for their action upon some property which is independent of the direction of the current, such as the heating effect or magnetizing force. The coherer used in Hertzian wave research is not metrical, since the action is merely catastrophic or accidental, and bears no very definite relation to the energy of the oscillation which starts it. Even the demagnetising action of electric oscillations, though more definite in operation than the contact action at loose joints, is far from being all that is required for quantitative research. It is obvious it would be an advantage if we could utilize the direct current mirror galvanometer for the detection and measurement of feeble electric oscillations. This can be done if we can discover a medium with perfect unilateral conductivity.

Some time ago, I considered the use of the aluminium-carbon electrolytic cell with this object. It is well known that a cell containing a plate of aluminium and carbon, immersed in some electrolyte which yields oxygen, such as

dilute sulphuric acid or an aqueous solution of any caustic alkali, or salt yielding oxygen, has a unilateral conductivity within limits. An electric current under a certain electromotive force can pass through the cell from the carbon to the aluminium, but not in the reverse direction.

This action has been much studied and is the basis of many technical devices, such as the Nodon electric valve.

The electrochemical action by which this unilateral conductivity is produced involves, however, a time element, and after much experimenting I found that it did not operate with high frequency currents. My thoughts then turned to an old observation made by me in 1889, communicated to the Royal Society, amongst other facts, in a Paper in 1889, and also exhibited experimentally at the Royal Institution in 1890.\* This was the discovery: that if a [fol. 2726] carbon filament electric glow lamp contains a pair of carbon filaments or a single filament and a metallic plate sealed into the bulb, the vacuous space between possesses a unilateral conductivity of a particular kind when the carbon filament, or one of the two filaments, is made incandescent. I have quite lately returned to this matter, and have found that this unilateral conductivity exists even with alternating currents of high frequency and is independent of the frequency. Hence, in a suitable form, it seemed possible that such a device would provide us with a means of rectifying electric oscillations and making them measurable on an ordinary galvanometer. The following experiments were, therefore, tried:—

Into a glass bulb, made like an incandescent lamp, are sealed in the ordinary way two carbon filaments, or there may be many filaments. On the other hand, one carbon filament may be used and a platinum wire may be sealed into the bulb terminating in a plate or cylinder of platinum, aluminium or other metal surrounding the filament. It is

\* See 'Roy. Soc. Proc.,' vol. 47, p. 122, 1890, "On Electric Discharge between Electrodes at different Temperatures in Air and High Vacua," by J. A. Fleming, communicated December 16, 1889; see also 'Proceedings of the Royal Institution,' vol. 13, Part LXXXIV, p. 45, Friday evening discourse on February 14, 1890, "Problems on the Physics of an Electric Lamp," when this unilateral conductivity was experimentally shown.

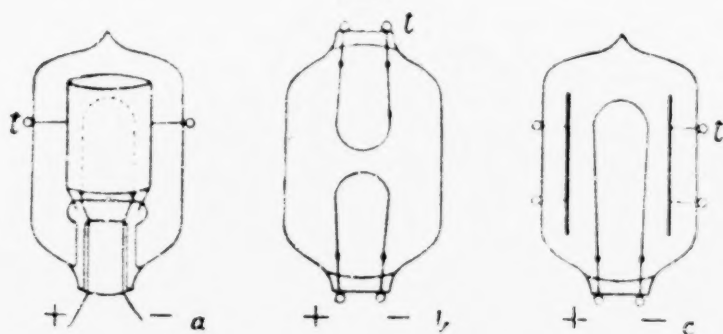
preferable to use a metal plate carried on a platinum wire sealed into the glass bulb, the plate being bent into a cylinder which surrounds both the legs of the carbon loop. The diagrams in fig. 1 show various forms of the arrangement. Diagram *a* shows a bulb with a single carbon filament surrounded by a metal cylinder, *b* shows one with two carbon filaments, and *c* a carbon filament and two insulated metal plates. The ends of the carbon filament which is rendered incandescent are marked + and - and the terminal of the other electrode of the valve is marked *t*. The bulb must be highly exhausted to about the pressure usual in the case of carbon filament incandescent lamps, and the metal cylinder or plate must be freed from occluded air.

Suppose that we employ such a bulb containing one carbon filament surrounded by a metal cylinder (see *a*, fig. 1). The filament may be of any voltage, but I find it most convenient to employ filaments of such a length and section that they are brought to bright incandescence by an E.M.F. of 12 volts. The voltage and section of the filament should be so arranged that the temperature of the filament corresponds with an "efficiency," as a lamp-maker would say, of 75 or 80 watts per candle. The filament is conveniently brought to incandescence by a small insulated battery of secondary cells. A circuit is then completed through the vacuum space in the bulb between the cylinder and the filament by another wire which joins the external terminal of the metal cylinder and that terminal of the carbon filament which is in connection with the negative pole of the driving battery. In this last circuit is placed a sensitive mirror galvanometer of the movable needle or movable coil (2727) type, and also a coil which may be the secondary circuit of an air core transformer in which electric oscillations are set up. As is now well known, the vacuum space in the bulb permits negative electricity to move in it from the hot filament or cathode through the vacuum space to the cylinder or anode and back through the galvanometer and coil, but not in the reverse direction, as long as the cylinder is cool and the carbon filament not at a temperature much above the melting point of platinum. To illustrate the action of the bulb as an electrical valve, the following experiments can be shown:

Electric oscillations are set up in a metal wire circuit by the discharge of a Leyden jar, as usual. This circuit

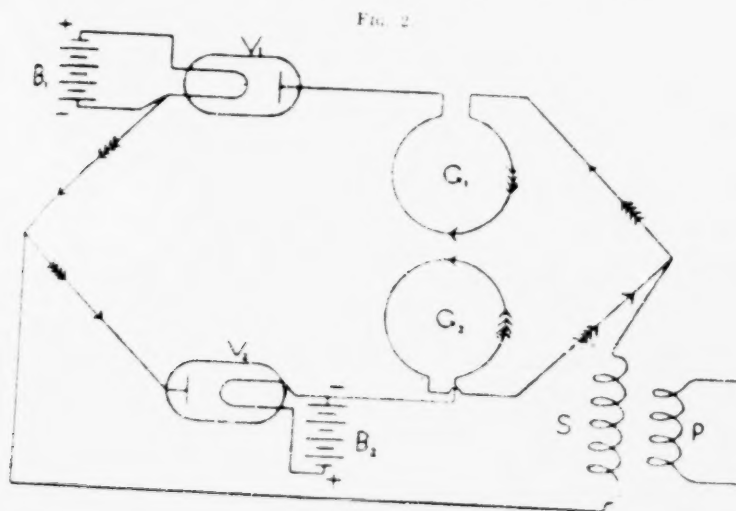
takes the form of a thick wire of one or more turns, bent into the form of a circle or square. Some distance from this, we place another wire, of several, say eight or ten

FIG. 1.



turns, also bent into the form of a circle, and connect this last wire into the circuit of a galvanometer and vacuum bulb made as described, so that it is a circuit having unilateral conductivity. On exciting the oscillations in the primary circuit by an induction coil we have an alternating high frequency magnetic field produced, which affects the secondary circuit at a distance. The oscillations in this last are, however, able to flow only in one direction. Hence, the galvanometer is acted upon by a series of intermittent but unidirectional electromotive forces, and its needle or coil deflects. Since the field is a high frequency field, we can show the screening effect of a sheet of tin foil or silver paper in a very simple and effective manner by the effect it produces in cutting down the galvanometer deflection when the metal sheet is interposed between the primary secondary circuits. Also, if we move the secondary coil away from the primary coil or turn the two coils with their planes at right angles to one another, then the galvanometer deflection diminishes or falls to zero because the induction is decreased. Accordingly, we have in this vacuum valve and associated [fol. 2728] mirror galvanometer a means of detecting feeble alternating electric currents or oscillations. Another method is to employ a differential galvanometer and two vacuum valves. These must then be arranged, as shown in fig. 2, one circuit  $G_1$  of the differential galvanometer is in series with one valve  $V_1$ , and the other circuit  $G_2$  with the other valve  $V_2$ , but so joined up that currents flowing through the valves in opposite directions pass round the two galvanom-

eter wires in the same direction as regards the needle and, therefore, their effects are added together on the galvanometer needle. Each valve must then have its own separate insulated battery to ignite the filament. Also, it is necessary that the connection with the oscillatory circuit must be made in both cases to the hot filament by that terminal which is in connection with the negative pole of the local battery used to ignite the filament (see fig. 2).



This arrangement of a differential galvanometer and two valves transforms, of course, more of the alternating oscillation into direct current than when one valve alone is used. It provides us with a means of detecting electrical oscillations not merely in closed circuits but in open electrical circuits.

When so using it, it is necessary to associate with the oscillation valve and galvanometer an oscillation transformer for raising the voltage. The resistance of these valves, when in operation, may be anything from a few hundred ohms up to some megohms, depending on the state of incandescence of the filament and upon the electromotive force employed to drive the current through the vacuum space, as well as upon the size of the filament and [fol. 2729] the plate. This resistance does not obey Ohm's law, but the current increases to a maximum and then slightly decreases as the voltage progressively increases. The form of oscillation transformer employed with the device is as follows: A small air core induction coil has

a primary circuit, which consists of 52 turns of gutta-percha covered wire, wound in a helical groove cut on an ebonite rod 0.5 inch in diameter and 6 inches in length. The primary circuit is made of a No. 20 or No. 22 S.W.G. copper wire. The secondary circuit consists of 36,000 turns of fine silk-covered wire, No. 36, wound in six coils, each having about 6000 turns, and all joined in series. This secondary circuit has one terminal connected to one common terminal of the galvanometer and the other to the common terminal of the two oscillation valves (see fig. 4). The primary coil of this oscillation transformer has one terminal connected to earth and the other to a long insulated rod which acts as an aerial or electric wave collector. To prevent the direct action of the transmitter upon the secondary coil by simple electromagnetic induction, it is best to wind the secondary coil in two equal parts in opposite directions and to wind the primary in a corresponding manner.

If an electric wave sent out from a similarly earthed transmitter falls upon the rod, then an electrical oscillation is set up in the receiving circuit and therefore in the primary coil of the oscillation transformer inserted in series with it. This oscillation is raised in voltage by the secondary coil of the transformer, and by reason of the unilateral conductivity of a vacuum valve, placed in series with the coil, one part of the oscillation, viz., the positive or the negative current, passes round the galvanometer coils and affects it.

If we employ a sensitive dead beat galvanometer of the type called by cable engineers a "Speaking Galvanometer," then intelligible signals can be sent by making small and larger deflections of the galvanometer corresponding to the dot and dash of the Morse alphabet; anyone who can "read mirror" can read off the signals as quickly as they can be sent on an ordinary short submarine cable with this arrangement.

The arrangement, although not as sensitive as a coherer or magnetic detector, is much more simple to use. Also it has one great advantage, viz., that it enables us to examine the behaviour of any particular form of oscillation producer. By means of it we can detect changes in the wave making power or uniformity of operation of the transmitting arrangement, by the variation of the deflection of the galvanometer. Thus, for instance, if a spark-ball transmitter is being employed and the deflection of the galvanometer in association with the receiving aerial is steady, if we put the

slightest touch of oil upon the spark balls of the transmitter, their wave-making power is increased and the deflection of the galvanometer at once increases. Since the current through the galvanometer is the result of the groups [fol. 2730] of oscillations which are created in the receiving circuit, and since in the ordinary transmitter these oscillation groups are separated by wide intervals of silence, it is obvious that we can increase the sensitiveness of the above described arrangement by employing a very rapid break or interruptor with the induction coil. If, for instance, we employ a Wehnelt break with the induction coil or a high-speed mercury break or alternating current transformer, we get a far better result as indicated by the deflection of the galvanometer than when employing the ordinary low frequency spring or hammer break.

The point of scientific interest in connection with the device, however, is the question how far such unilateral conductivity as is possessed by the vacuum space is complete. The electrical properties of these vacuum valves have accordingly been studied.

A bulb containing a 12 volt carbon filament rendered brightly incandescent by a current of about 2.7 to 3.7 amperes was employed. The filament was surrounded by an aluminium cylinder. The length of the carbon filament was 4.5 cm., its diameter 0.5 mm., and surface 70 square mm.

The aluminium cylinder had a diameter of 2 cms., a height of 2 cms., and a surface of 12.5 square cms. The filament was shaped like a horse shoe, the distance between the legs being 5 mm. This filament was rendered incandescent to various degrees by applying to its terminals 8, 9, 10, and 11 volts respectively. Another insulated battery of secondary cells was employed to send a current through the vacuum space from the cylinder to the filament, connection being made with the negative terminal of the latter. The current through the vacuum space and the potential difference of the cylinder and negative end of the hot carbon filament were measured by a potentiometer. The effective resistance of the vacuum space is then taken to be the ratio of the so observed potential difference (valve P.D.) to the current (valve current) through the vacuum.

The following table records the observations. The column headed P.D. gives the potential difference between the hot filament and the cylinder, that headed A gives the

current through the vacuum space in milliamperes, that headed R the resistance of the space in ohms, and that headed  $K10^6$  is 100,000 times the conductivity.

The result is to show that the vacuum space does not possess a constant resistance, but its conductivity increases rapidly up to a maximum and then decreases as the valve potential difference progressively increases. If we plot the current values as ordinates and potential difference of the valve electrodes as abscissæ, we find that the current curve quickly rises to a maximum value and then falls again slightly as the potential difference increases steadily. The conductivity curve also rises to a maximum and then decreases (see fig. 3).

The facts so exhibited are well-known characteristics of [vol. 2731] gaseous conduction in rarified gases.\* It may be noted that there is in these current-voltage and voltage

Table I. Variation of Current through, and Conductivity of, a Vacuum Valve with varying Electromotive Force, the Electrodes being an Incandescent Carbon Cathode and Cool Aluminium Anode

Carbon filament at 11 volts, 3.77 amp., 41.47 watts				Carbon filament at 10 volts, 3.44 amps., 34.43 watts.			
Vacuum Space				Vacuum Space			
P. D.	A.	R.	$K10^6$	P. D.	A.	R.	$K10^6$
0.6	0.024	25.000	4.0	0.7	0.014	50.000	2.0
5.4	0.264	20.550	4.86	2.8	0.073	38.360	2.6
8.8	0.480	18.330	5.45	8.2	0.392	20.920	4.76
18.2	3.880	4.691	21.4	12.8	0.824	15.530	6.56
22.9	26.790	855	118.1	16.2	1.739	9.316	10.70
29.1	28.02	1.038	96.1	20.1	5.352	3.756	26.6
37.1	28.426	1.305	76.6	23.3	9.68	2.407	41.4
49.0	26.50	1.719	58.0	35.9	10.037	3.577	28.0
70.2	26.87	2.613	38.3	49.7	9.794	5.075	20.0
100.0	24.36	4.105	25.0	71.6	8.920	8.027	12.5
				100.98	8.331	12.010	8.32

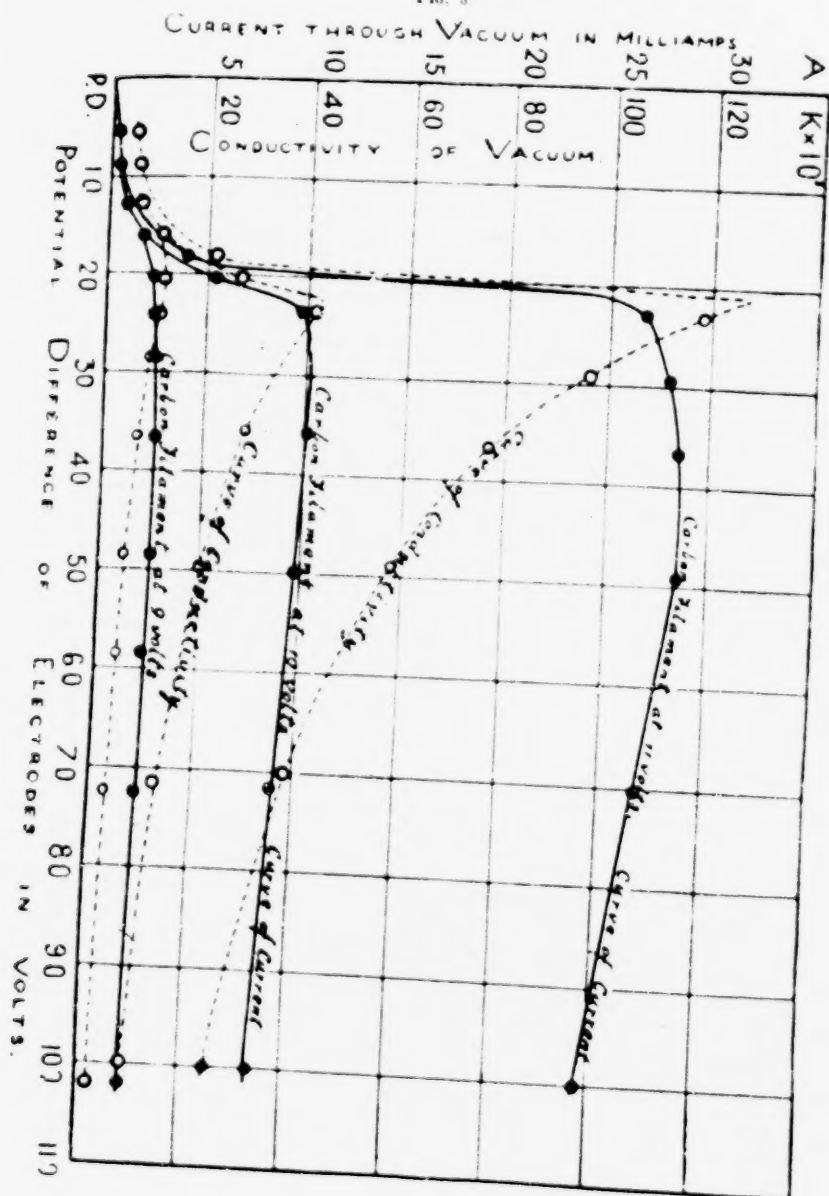
Carbon filament at 9 volts, 3.112 amps., 28.0 watts			
Vacuum Space			
P. D.	A.	R.	$K10^6$
0.5	0.005	100.000	1.0
2.5	0.049	50.020	2.0
5.2	0.128	49.625	2.46
8.3	0.324	25.620	4.0
8.8	0.361	24.380	4.1
12.6	0.70	17.970	5.5
16.4	1.735	9.452	10.5
20.4	2.351	8.677	11.2

\* See J. J. Thomson, 'Conduction of Electricity through Gases,' Chap. VIII.

conduction curves a general resemblance to the magnetisation and permeability curves of iron.

To examine further the nature of this conduction, the following experiments were made. If a vacuum bulb, as described, is joined up in series with a galvanometer and an electro-dynamometer and an alternating electromotive force applied to the circuit, the two instruments will be both affected. The galvanometer is, however, affected only by

FIG. 3



[fol. 2732] the resultant flux of electricity in one direction. It measures the unidirectional current. The dynamometer is affected by the bilateral flux of electricity and it measures the total or alternating current. If, therefore, the vacuous space is totally non-conducting in one direction, one half [fol. 2733] of the alternating current will be cut out. The galvanometer will read the true mean (T.M.) value of the remanent unidirectional current, and the dynamometer will read the root-mean-square (R.M.S.) value. If the conductivity in one direction is not zero, then the galvanometer will read the T.M. value of the difference of the positive and negative currents, but the dynamometer will read the R.M.S. value of their sum.\*

In the last case, the current through the valve may be considered to be a continuous current superimposed upon an alternating current.

If we call  $I$  the maximum value of the nearly sinoidal current in one direction, and  $I'$  the maximum in the opposite direction, then we may say that the dynamometer reading ( $D$ ) expressed in true current value is equal to  $g(I+I')$  where  $g$  is the *amplitude factor*, and also that the galvanometer reading ( $G$ ) in true current value is equal to  $g f(I-I')$ , where  $f$  is the *form factor* of the current.† Hence—

$$\frac{D}{G} = f \frac{I+I'}{I-I'} \text{ or } \frac{D}{G} \frac{G^2 + f^2}{2f} = \frac{1}{1 - f^2}$$

The fraction  $\frac{2f}{D/G + f}$ , say  $B_v$ , expressed as a percentage may be called the *rectifying power* of the valve, for it expresses the percentage which the actual unilateral electric flow or continuous current through the valve is of that con-

\* If  $i$  is the instantaneous value of a periodically varying current with maximum value  $I$  and periodic time  $T$ , then the root-mean-square value (R.M.S. value) of  $i$  is defined to be  $\left(\frac{1}{T} \int_0^T i^2 dt\right)^{\frac{1}{2}}$  and the true mean value (T.M. value) of  $i$  is defined to be  $\frac{2}{T} \int_0^{\frac{1}{2}T} i dt$ .

† The *form factor*  $f$  and *amplitude factor*  $g$  are the names given by the author (see 'Alternating Current Transformer,' J. A. Fleming, vol. 1, p. 585, 3rd edit.) to the ratio of the R.M.S. to the T.M. value of the ordinates of a single valued periodic curve, and to the ratio of the R.M.S. value of the ordinates to the maximum value during the period.

tinuous current which would flow if the unilateral conductivity were perfect.

Perfect rectifying power, however, does not exist. There is not an infinite resistance to movement of negative electricity from the metal cylinder to the hot filament through the vacuum, although this resistance is immensely greater than that which opposes the movement of negative electricity in the opposite direction. This point was examined, as follows: A very sensitive electro-dynamometer was skillfully constructed by my assistant, Mr. G. B. Dyke, the fixed coil having 2000 turns of No. 47 silk-covered copper wire and the movable coil 1000 turns. The suspension of the movable coil was by a fine flat phosphor-bronze wire at top and bottom. The deflection was observed by a mirror and scale.

[fol. 2734] This dynamometer was placed in series with a shunted movable coil galvanometer of Holden Pitkin pattern, and the two together placed in series with a variable section of an inductionless coil through which an alternating current was passing. A vacuum valve as above described was in series also with the galvanometer and dynamometer. The alternating current was derived from an alternator giving a nearly true sinoidal electromotive force. The form factor of the electromotive force curve of this alternator was determined and found to be 1.115, that for a true sine curve being 1.111.

The vacuum valve sifted out the alternating current flow and allowed the currents in one direction to pass, but nearly stopped those in the opposite direction. The indications of the electro-dynamometer were proportional to the root-mean-square (R. M. S.) value of the sum of the two opposite currents, and that of the galvanometer to the true mean value (T. M.) of their difference. The galvanometer and dynamometer were both calibrated by a potentiometer by means of continuous current, and curves constructed to convert their scale readings to milliampères. Then with various alternating current electromotive forces, their readings were taken when in series with a vacuum valve and recorded in the following tables. The letter D denotes current in milliampères as read by the so calibrated dynamometer and G that read by the galvanometer. The ratio D/G is denoted by  $\alpha$ , and the rectifying power, viz.,  $2f/\alpha + f$  by  $\rho$ .

The table shows that the value of  $\alpha$  is not constant, but for each state of incandescence of the filament reaches a maximum which, however, does not greatly differ from the mean value for the range of currents used. If we set out the mean values of  $\beta$  in a curve (see fig. 4), in terms of the power expended in heating the carbon filament, we see that the rectification is less complete in proportion as the temperature of the carbon filament increases. This is probably due to the fact that as the filament gets hotter, it heats the enclosing cylinder to a higher temperature and enables negative electricity to escape from the latter.

Hence, I feel convinced that if the metal cylinder could be kept quite cool by water circulation the rectification would reach 100 per cent. or be complete.

An ideal and perfect rectifier for electric oscillations may, therefore, be found by enclosing a hot carbon filament and a perfectly cold metal anode in a very perfect vacuum. With a bulb such as that used for the above experiments all we can say is that the current passed through the vacuum is from 80 to 90 per cent. continuous, 100 per cent. implying that the vacuum is perfectly non-conducting in one direction and permits the flow of negative electricity only from the hot to the cold electrode. The necessity for keeping the cathode cold is shown by the following experiment:—An alternating-current arc was formed between

(vol. 2735)

Table II. Ratio of Electrodynamometer (D) to Galvanometer (G) Reading in Milliampères. Form Factor of E. M. F. Curve = 1.115 =  $f$ .

Carbon filament at 11 volts, 3.77 amps., 41.7 watts.

D	G	$D/G = \alpha \cdot 2f \alpha + f = \beta$	
0.85	0.57	1.49	0.85
1.33	0.85	1.56	0.83
1.87	1.16	1.61	0.82
2.30	1.40	1.64	0.81
3.20	1.88	1.73	0.78
3.52	2.19	1.68	0.80
4.54	2.81	1.62	0.82
Mean = 0.82			

Carbon filament at 10 volts, 3.44 amps., 34.43 watts.

D	G	$D/G = \alpha \cdot 2f \alpha + f = \beta$	
0.50	0.34	1.47	0.86
1.34	0.86	1.56	0.83
2.28	1.48	1.54	0.84
2.72	1.68	1.62	0.82
2.78	1.71	1.63	0.81
3.02	1.87	1.62	0.82
3.53	2.17	1.63	0.81
4.30	2.92	1.47	0.86
4.25	2.88	1.48	0.86
Mean = 0.83			

Carbon filament at 9 volts, 3.112 amps, 28.0 watts

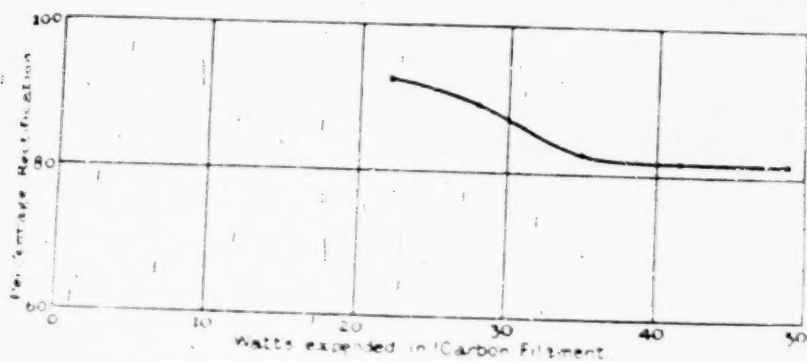
0.40	0.31	1.29	0.93
0.73	0.50	1.46	0.84
1.28	0.83	1.54	0.84
1.65	1.15	1.43	0.88
1.82	1.26	1.44	0.87
1.78	1.26	1.41	0.88
1.93	1.35	1.43	0.89
1.94	1.41	1.38	0.89
1.87	1.41	1.38	0.91
1.83	1.39	1.32	0.92
1.73	1.37	1.26	0.94

Mean  
0.89

carbon rods, and an iron rod was placed so that its end dipped into the arc. An ammeter was connected in between either carbon and the iron rod, and indicated a continuous current of negative electricity flowing through the ammeter from the iron rod to the carbon pole. This current was, however, greatly increased by making the iron rod of a piece of iron pipe closed at the end and kept [fol. 2736] cool by a jet of water playing in the interior. In this manner I have been able to draw off a continuous current of 3 or 4 ampères from an alternating-current arc using 15 alternating-current ampères.

Returning, then, to the vacuum valve, we may note that the curves in fig. 3 show that the vacuum space possesses a maximum conductivity corresponding to a potential difference of about 26 volts between the electrodes, for the particular valve used. The interpretation of this fact may, perhaps, be as follows:—In the incandescent carbon there is a continual production of electrons or negative ions by atomic dissociation. Corresponding to every temperature there is a certain electronic tension or percentage of free electrons. If the carbon is made the negative electrode in

FIG. 4



a high vacuum these negative ions are expelled from it, but they cannot be expelled at a greater rate than they are produced. Therefore, there is a maximum value for the outgoing current and a maximum value for the ratio of current to electromotive force, that is for the conductivity.

This fact, therefore, fixes a limit to the utility of the device. The current through the vacuum space is, to a very large extent, independent of the electromotive force creating it, and is at no stage proportional to it, or at least only within a narrow range of electromotive force near to the maximum conductivity.

Whilst, therefore, the device is useful as a simple means of detecting electric oscillations, it has not that uniformity of conductivity which would make it useful as a strictly metrical device for measuring them. It can, however, perform the useful service of showing us how far any device for producing electric oscillations or electric waves produces a uniform or very irregular train of electric oscillations, and what changes conduce to an improvement or reduction in the efficiency of the transmitting device.

No. 843,327

L. DE FOREST

PATENTED JAN. 15, 1907.

DEVICE FOR AMPLIFYING FEIBLE ELECTRICAL CURRENTS.

APPLICABLE TO RADIO-RECEIVERS.

FIGURE 1. SHEET 1



Fig. 1.

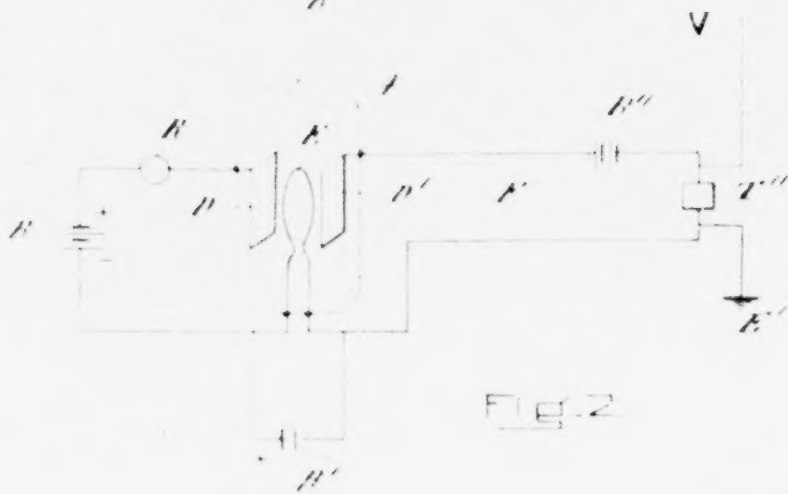


Fig. 2.



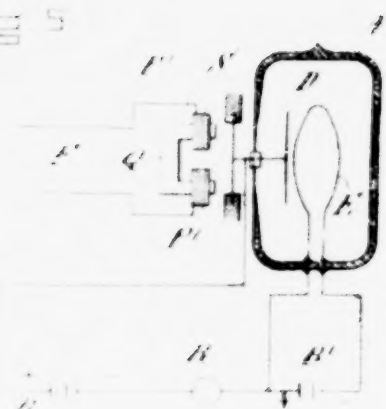
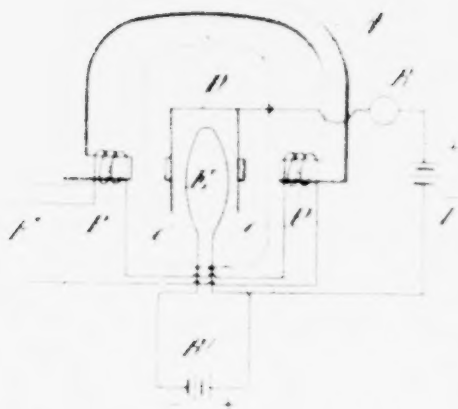
Fig. 3.

WITNESSES:

E. B. Tomlinson  
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Lee de Forest  
by Joseph Woodworth  
Attorney



WITNESSES:

J. B. Tomlinson  
Calcutt & Conroy

FIG. 6

FIG. 7 INVENTOR

L. de Forest  
by Geo. H. Woodworth  
Attorney

# UNITED STATES PATENT OFFICE.

LEE DE FOREST, OF NEW YORK, N. Y.

## DEVICE FOR AMPLIFYING FEEBLE ELECTRICAL CURRENTS.

No. 841,387.

Specification of Letters Patent.

Patented Jan. 15, 1907.

Application filed October 25, 1906. Serial No. 340,487.

*To all whom it may concern:*

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful Improvement in Devices for Amplifying Feeble Electrical Currents, of which the following is a specification.

My invention relates to devices for amplifying feeble electrical currents—such, for example, as telephone-currents; and its object is to produce an amplifying device of greater efficiency and simplicity than those heretofore employed.

My invention will be described with reference to the drawings accompanying and forming a part of this specification, and in which—

Figures 1, 2, 3, 4, 5, 6, and 7 represent conventionally or diagrammatically various arrangements of apparatus and circuits whereby my invention may be carried into effect.

In the figures, A represents an evacuated vessel inclosing a sensitive conducting gaseous medium maintained in a condition of molecular activity.

R is a signal-indicating device.

BB are batteries or other sources of electrical energy.

DE D' are electrodes sealed within the receptacle A.

The circuit B R D E is a local receiving-circuit. The circuit F is a line-circuit conveying the currents to be amplified to the amplifying device. The electrode E, which may be of platinum, tantalum, carbon, or other suitable material, is heated and preferably maintained incandescent by the battery B'. The electrodes D and D', which may be plates of platinum or other suitable material, are placed in close proximity to the electrode E, and when the electrode D' is employed its separation from the electrode E preferably is less than that of the electrode D therefrom.

In Fig. 1, N S represent a magnet placed adjacent to the vessel A. The currents to be amplified may be impressed upon the circuit which includes the heated electrode or filament E—as, for example, by means of the transformer M—and the magnetic field set up by these currents reacts upon the field set up by the magnet N S, thereby causing a slight variation in the separation between the electrodes D E. I have found that the slightest variation in the separation of the

hot and cold electrodes produces a large and disproportionately greater variation in the flux between said electrodes, especially if the latter are close together, and such variation in flux may be made manifest by the signal-indicating device R.

In Fig. 2 the current to be amplified may be impressed upon the medium intervening between the electrodes D and E, and thereby alter, by electrostatic attraction, the separation between the electrodes. In this case D' may be a strip of platinum-foil, and the slightest approach thereof toward the filament will act to slightly cool the gaseous medium, and thereby alter the current in the local circuit, or, if D' is rigid, the increase in electrostatic attraction between D' and E will cause E to recede from D, and thereby alter the current in the local circuit.

In Fig. 3 the filament E is connected, by means of a minute platinum wire I, to the arm J which is secured to the coil a, placed between the poles of the magnet H and secured to the walls of the vessel A through the spiral springs b b. The line-current to be amplified in this case is passed through the coil a through the springs b b, and the resulting rotation of the coil varies the separation between the electrodes D E, thereby altering the current in the local circuit.

In Fig. 4 the currents to be amplified may be impressed upon the gaseous medium intervening between D' and E by means of the transformer M'. A condenser C may be included in series with the secondary of said transformer and the electrodes D' E. In this case there may or may not be a variation between the separation of the electrodes, and the currents to be amplified may vary the motions of the ions around the filament, thereby controlling to a greater degree the flux between said filament and the electrode D.

In Fig. 5 the currents to be amplified may be passed through the solenoid surrounding the magnet N S, and thereby vary the field, which by reacting with the magnetic field surrounding the electrode E determines the normal separation of the electrodes D and E. Even without creating actual movements between the electrodes D and E the varying magnetic flux produced by the line-current passing through the solenoid L will affect the motion of the ions in the gaseous medium, and thereby alter the current in the local circuit.

In Fig. 6 the electrode D may be consti-

tuted of iron or may consist of platinum plates provided with small iron armatures (O). In either case the currents to be amplified by passing through the solenoids P P, which surround the poles of the magnet N, effect the desired variation in the separation of the electrodes D and E.

In Fig. 7 the electrode D and diaphragm S may both be rigidly secured to the inside and outside, respectively, of the glass wall of the vessel A at a point where said wall has been flattened and made very thin, like the crystal of a watch. The currents to be amplified in this case by operating upon the coils P P, surrounding the magnet Q, effect slight movements of the diaphragm S, and these movements are mechanically transmitted through the glass wall of the vessel A to the electrode D, thereby varying the current in the local receiving circuit.

It will be obvious that the amplifying device, which constitutes the subject-matter of the present invention, is not limited in its use to any particular kind of electrical circuit or apparatus, but that it is capable of general application wherever an amplifying device is required. By way of example of its application to a wire telegraph or cable system I have shown the line E in Fig. 1 as including a telegraph transmitting key T, and source of vibratory current G. In Fig. 2 I have shown the line E as constituting the local circuit of a wireless telegraph receiving system including the battery B' and oscillation detector T', the latter being connected in series with an antenna V and the earth E'. In Fig. 3 I have shown the line E as constituting a telephone circuit including the microphone-transmitter T" and battery B. In all instances it will be understood by those skilled in the art and without going into further detail that the signal-indicating device R, which is included in the local receiving circuit, may be any device suitable for the purpose of reproducing the signal initiated in the line E.

I do not limit myself to any of the specific embodiments of my invention herein described, inasmuch as many modifications will readily occur to those skilled in the art without departing from the principle of my invention.

I write:

1. In a device for amplifying electrical currents, an evacuated vessel inclosing a semi-rigid conducting gaseous medium inclosed in a condition of molecular activity, two electrodes sealed within said vessel, a local receiving-circuit associated with said elec-

trodes, and means whereby the separation of said electrodes may be varied by the currents to be amplified.

2. In a device for amplifying electrical currents, an evacuated vessel, two electrodes sealed within said vessel, means for heating one of said electrodes, a local receiving-circuit associated with said electrodes, and means whereby the separation of said electrodes may be varied by the currents to be amplified.

3. In a device for amplifying electrical currents, an evacuated vessel, two electrodes sealed within said vessel, a circuit including a source of electric energy connected in series with one of said electrodes, a local receiving-circuit associated with said electrodes, and means whereby the separation of said electrodes may be varied by the currents to be amplified.

4. In a device for amplifying electrical currents, an evacuated vessel, three electrodes sealed within said vessel, means for heating one of said electrodes, a local receiving-circuit including two of said electrodes, and means for passing the current to be amplified between one of the electrodes which is included in the receiving-circuit and a third electrode.

5. In a device for amplifying electrical currents, an evacuated vessel inclosing a gaseous medium, means other than the received energy for maintaining said gaseous medium in a condition of molecular activity, means for impressing the currents to be amplified upon said gaseous medium, and a local receiving-circuit having its electrodes sealed within said vessel.

6. In a device for amplifying electrical currents, an evacuated vessel, a heated anode and two non-heated electrodes sealed within said vessel, the non-heated electrodes being unequally spaced with respect to said heated electrode, a local receiving-circuit including said heated electrode and that one of the non-heated electrodes, which has the greater separation from the heated electrode, and means for passing the current to be amplified between the heated electrode and the other non-heated electrode.

In testimony whereof I have hereunto subscribed my name this 17th day of February, 1910.

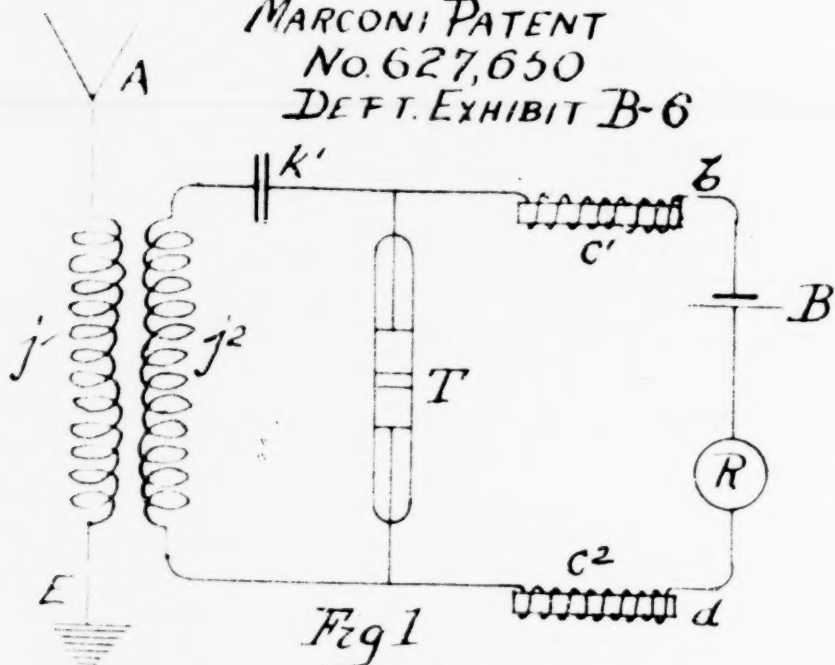
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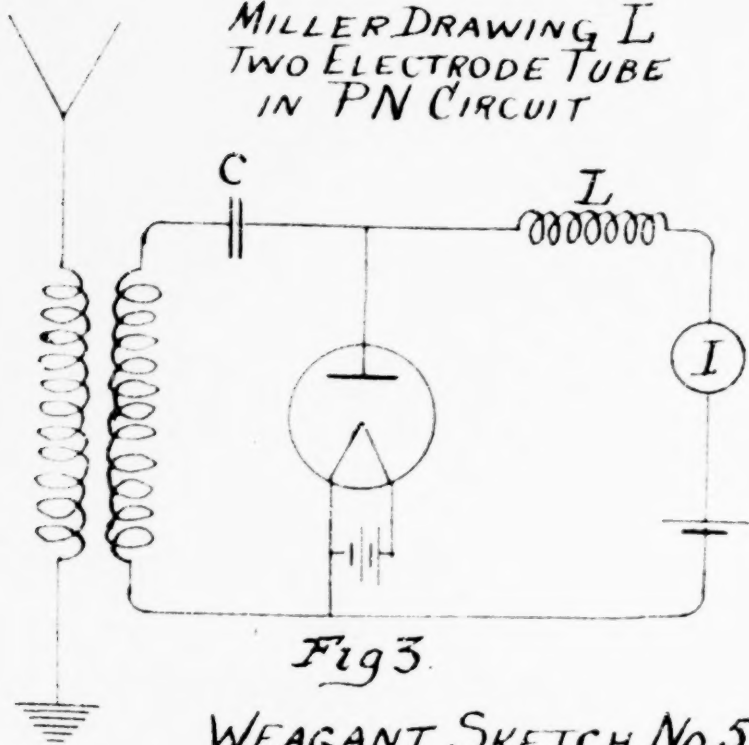
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Claimant's Exhibit No. 273

MARCONI PATENT  
No. 627,650  
DEFT. EXHIBIT B-6



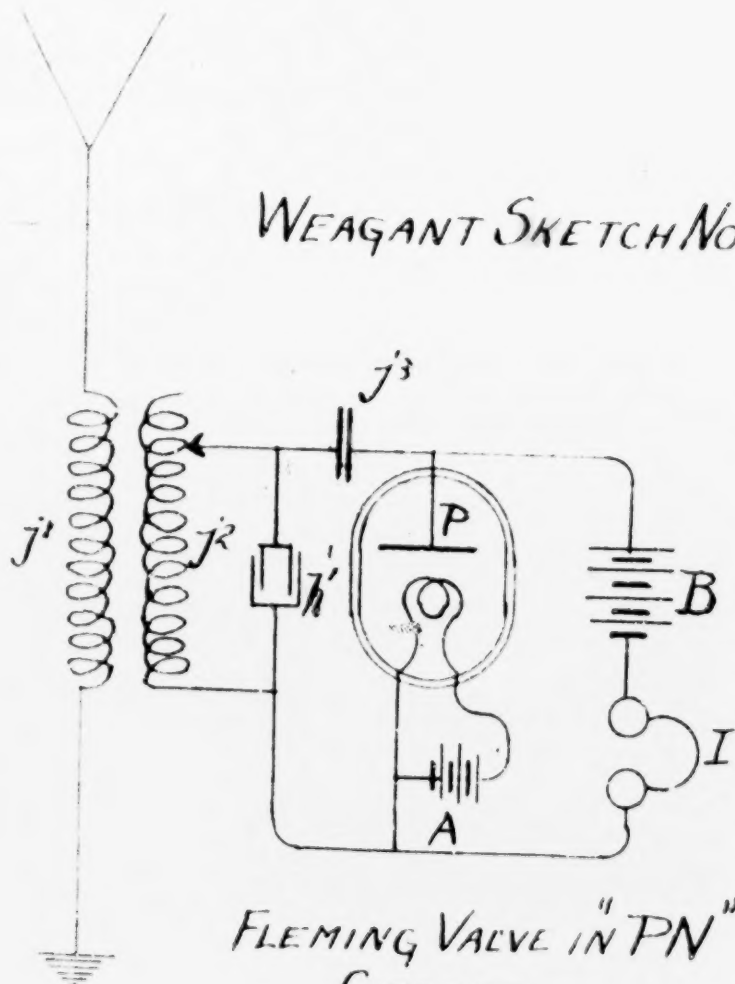
MILLER DRAWING L  
TWO ELECTRODE TUBE  
IN PN CIRCUIT



WEAGANT SKETCH No 5.

Claimant's Exhibit No. 274

WEAGANT SKETCH NO. 6.



FLEMING VALVE IN "PN"  
CIRCUIT.

2742

2743

## PLAINTIFF'S EXHIBIT 275

## DETECTORS

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metal-copper pyrites, metal-chalcocite, metal-manganese dioxide, metal-inferium. He proved that:

1. These detectors are sensitive only if the contact is limited to a point.
2. They operate without a battery in series, and when a battery is used the sensitiveness does not depend upon the value or direction of its e.m.f.
3. The direction of the current (direct) obtained under the influence of the received oscillations is always the same as the direction of the thermo-e.m.f.

With another group, however—carborundum, anatase (titanium dioxide), molybdenite and the perikon detector—Tissot's tests established that:

1. The form of the contact is of little or no importance, even relatively large polished plates placed between two metallic electrodes make sensitive detectors.
2. The use of a battery in series with the detector, with proper value and direction of the battery e.m.f., increases the sensitiveness.
3. The sensitiveness of these detectors bears no relation whatever to the value of their thermo-e.m.f.

He, therefore, concludes that in this last mentioned group thermoelectric forces play no important part in their action as detectors.

G. W. PIRACE,<sup>1</sup> as the result of extensive investigations, including oscillograph records made with the BRAUN tube, concluded that with carborundum, anatase, brookite (another form of  $TiO_2$ ) and silicon, thermoelectric forces were not involved, but that these detectors were better conductors in one direction than in the other, in short, act as rectifiers [Art. 162].

161. Incandescent Lamp Detectors, Gas Detectors.—a. J. A. FLEMING<sup>222</sup> observed the following phenomenon: An electrode (A, Fig. 340), say of cylindrical form, is fused into an incandescent lamp bulb, whose filament is made incandescent by means of a battery, B.\* A circuit containing a galvanometer, G, (or telephone) and a coil,  $S_2$ , is joined to the electrode, A, at one end and to the lamp filament, at the other, K. The aerial coil  $S_1$  is coupled with  $S_2$ ; hence if oscillations pass through  $S_1$ , the oscillations induced in the circuit AGS<sub>2</sub>K will cause the galvanometer to deflect (or produce a sound in the telephone). The galvanometer needle will return to its zero position as soon as the oscillations cease, i.e., the arrangement is a self-restoring wave indicator.

Several years ago C. TISSOT<sup>223</sup> used this wave indicator for measurements over considerably long ranges but he complains of the irregularity

\* A choke coil [Art. 169] should be inserted in the leads from the battery to the lamp.

of the deflections.\* But in the more recent form of FLEMING's "oscillation-valve," the anode being a cylinder of carbon and the cathode a tungsten wire, this detector seems to have met all reasonable requirements as to sensitiveness and reliability. This is borne out by the fact that MARCONI has been using it, in conjunction with an EINTHOVEN string galvanometer, in his transatlantic stations.

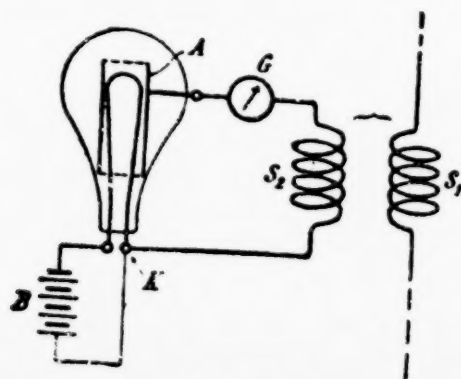


FIG. 340.

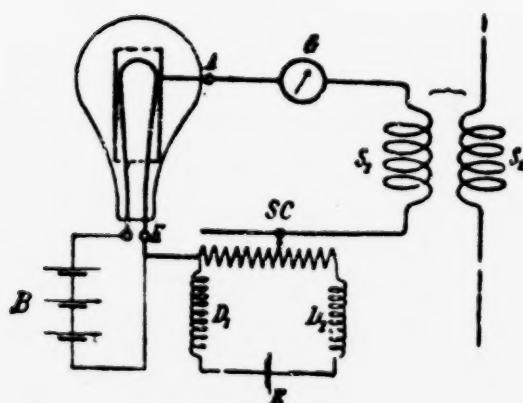


FIG. 341.

The incandescent lamp may be replaced by the tube devised by A. WEHNELT<sup>266</sup> which operates in the same manner. The incandescent cathode of this tube is a wire coated with a metallic oxide, and the anode is a hollow aluminium cylinder, concentric with the cathode.

b. H. BRANDES<sup>267</sup> has found that it is very advantageous to insert an auxiliary battery or cell, *E*, about as shown in Fig. 341,† when using

\* TISSOT<sup>265</sup> describes a wave indicator using rarified air (as in the ZEUNER tube), which he found to be less sensitive but better adapted for measuring purposes.

† *D*<sub>1</sub> and *D*<sub>2</sub> are inductive coils.

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[fol. 2745]

PLAINTIFF'S EXHIBIT 276

## Chapter III

*Valve Detectors and Detector Relays*

In the previous Chapter it has been pointed out that the plate current curve of a hard valve is of such a shape that the valve has got rectifying properties. When functioning as a detector at the lower bend of the curve the grid potential in the general case is negative compared with the filament and the grid current is zero; the grid circuit has infinite resistance and hence the valve abstracts no energy from the oscillating circuit to which it is connected, the necessary pulses of telephone current coming from the plate circuit battery. *Thus a valve employed in this way as a detector has very little damping effect on the oscillating circuit*, therefore tuning will be sharp, and loose coupling to the aerial circuit can be employed so that jamming by interference is reduced.

The damping effects of the valve are not entirely zero, for there is a small capacity effect between the grid and the other electrodes which allows some oscillating energy to pass; on account of this the valve may not be as good a detector as a good crystal on short waves at high frequencies.

Before discussing further the methods of using a hard valve for rectification it may be interesting to briefly consider some of the earlier types of valves which were used on wireless receiver circuits.

**Fleming Valve.**—The first valve detector was patented by Dr. J. A. Fleming in 1904; it had no grid, and simply made use of the unilateral conductivity effect between a heated filament and a plate enclosed together in a vacuum. At that time it was considered so reliable and robust compared to crystal detectors that it was largely adopted on wireless installations by the Marconi Company.

The detector consisted of a small electric lamp with a single hairpin filament of tungsten or carbon, surrounded by a cylinder of sheet or gauze copper, or nickel, which was attached to a third terminal on the lamp.

[fol. 2746] The filament was heated to incandescence by means of a battery, of from 4 to 12 volts depending on the size of the valve, in series with a regulating resistance. The

negative side of the filament was connected in series with a potentiometer voltage and telephone receivers to one side of the wireless receiver circuit, the copper plate or anode to the other side of the circuit.

The valve had a soft vacuum and was what we would now call a "gas valve"; its sensitiveness to signals was not so good as that of a good crystal combination, but the sensitiveness was not impaired by strong signals and atmospherics.

Fig. 12 shows a Fleming Valve as supplied by the Marconi Company; also its connections to a receiving circuit.

Fleming was the first to use the uniliteral conductivity

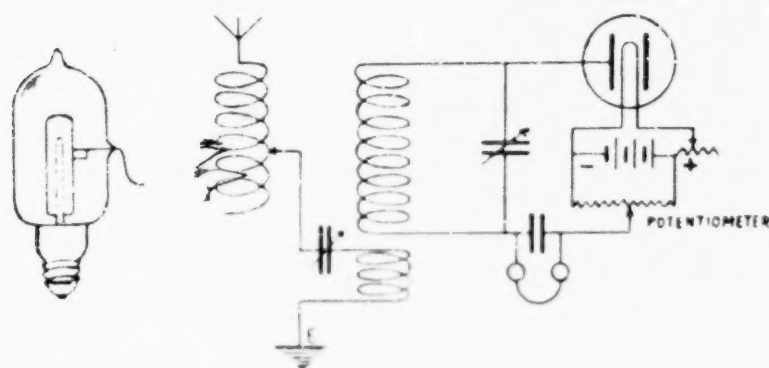


FIG. 12

effects of an electron discharge, from a heated filament to a plate at a higher potential than the filament, so that his patent may be considered as the parent one of all valves used in wireless receiver circuits.

**Lieben-Reisz Valve.** The use of a grid between the plate and filament seems to have been first applied commercially by Lieben and Reisz in their valve relay, which was used by them for relaying low frequency, or telephonic, current pulses. It is described in Chapter VI, dealing with Low Frequency Amplification.

**"Audion" Valve.**—Dr. De Forest introduced a grid consisting of a perforated cylinder, or plate, between the filament and anode of what was virtually a Fleming valve, thus producing a relaying valve which he called an [fol. 2747] "Audion." In De Forest's circuit, which is shown in Fig. 13, the valve is used as a detector relay; the small pulses of potential set up in the receiver circuit act on the grid and cause corresponding pulses of plate circuit

current; these are also rectified by employing the valve at the proper point on its characteristic curve.

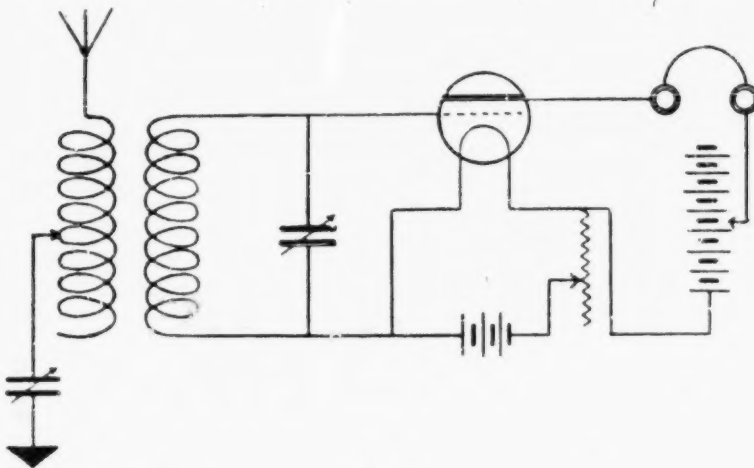


FIG. 13.

**Round's Valve.**—The soft vacuum Round valve was much superior to any which had preceded it, and was of such a size that comparatively large current pulses were dealt with in the plate filament circuit. It had a hairpin platinum filament coated with a mixture of barium and calcium oxides; completely surrounding the filament was a thimble of fine mesh nickel wire which formed the grid, while a nickel cylinder surrounded this again to form the plate. Like all soft valves it was very sensitive to grid potential, which was regulated by a potentiometer in series with the grid; it was also very sensitive to the degree of vacuum, in other words its sensitiveness depended greatly on the ionisation effects, as has been described in the previous Chapter.

In order to counteract the tendency of the valve to harden with continued use a pellet of asbestos was enclosed in a small neck at the top of the valve; heating this by a match would drive from it gas molecules into the body of the valve, and thus the vacuum could be brought to the proper degree of softness. The necessity of thus regulating the vacuum was a disadvantage, also the facts that when started up the valve did not come into proper

## PLAINTIFF'S EXHIBIT 282

## BRITISH PATENT

~~No. 28,355 A.D. 1886.~~

3

~~Improvements in Means of Telegraphing or Telephoning without Wires~~  
~~sound signal when the Apparatus is used for Telegraphing, instead of Telephoning~~  
~~as described in the first portion of this Specification.~~

~~Dated this 14th day of September 1886.~~

~~A. C. BROWN.~~  
~~GEO. R. NEILSON.~~

5

## COMPLETE SPECIFICATION.

Improvements in Means of Telegraphing or Telephoning without  
Wires.

ALFRED CHARLES BROWN, Electrician, and GEORGE RICHARD NEILSON, Secretary  
 10 to Public Company, both of 50 Old Broad Street in the County of London do  
 hereby declare the nature of this invention and in what manner the same is to be  
 performed, to be particularly described and ascertained in and by the following  
 statement:—

It has been known for some time past that waves of Electric energy of certain  
 15 periodicities or numbers of vibrations per second, known usually as Hertzian  
 waves, are capable of being radiated or projected so as to act on other Electric cir-  
 cuits placed at a distance, and produce certain effects therein, such as sparking  
 between disconnected conductors, and the alteration in resistance of loose contacts  
 or "Coharers" etc. It has been known too that these effects are manifested  
 20 through considerable distances in space and through various media which are in  
 some cases opaque to ordinary light.

The purpose of the present invention is to render the above-mentioned  
 phenomena more practically applicable to certain purposes of signalling, and for  
 Telephoning without wires.

25 For this purpose when a signalling Telegraph only is required we provide at,  
 or in connection with, the Transmitting Station a set of Apparatus for producing  
 the rays, such as a current generator and induction coil, or a high tension Electric  
 Machine, and a Hertzian Oscillator or Radiator, that is a pair of Electrodes, having  
 an inductive action on one another, and designed to suddenly equilibrate opposite  
 30 electric charges, impressed on them by an outside source (the induction coil or  
 electric machine) by violent electric surgings preferably across a spark gap, or  
 number of gaps thereby radiating energy into space. Any existing form of such  
 Oscillator or Radiator may be used for the present purpose, as the three ball  
 variety, consisting of one large central and two smaller charging balls, one on each  
 35 side, but we prefer to use a modification of the form, designed by Professor Righi,  
 wherein the spark is taken between a pair of balls, or electrodes, immersed in an  
 insulating liquid, such as oil. In place of using balls for the Electrodes, however,  
 we prefer to use more elongated rods with convex rounded, or half ball ends, as we  
 find that the radiation from these is stronger than from balls & this form of elec-  
 40 trode is useful whether immersed in liquid or not. We prefer however to incline  
 these rods upwards or else to curve them upwards somewhat crescent-shaped, so  
 that they may stand on insulating supports in a vessel of the insulating liquid,  
 and their outer ends (that is those most distant from the pair of ends which oppose  
 one another) project up out of the liquid, so that the charging sparks from the  
 45 machine, or induction coil may more conveniently be impressed upon them. Our  
 improved Radiator, constructed on this principle, is shewn in Fig. 1, wherein A A

*Improvements in Means of Telegraphing or Telephoning without Wires*

are the elongated Electrodes, (the dotted lines indicating the optional straight form) B the vessel made of insulating material and containing the oil or other insulating liquid and C C the two small charging balls or Electrodes connected to the poles of the machine or induction coil secondary. It will be seen that this construction gives great facility for adjusting the spark gaps and is simple and the vessel not requiring any special shaping is not liable to leak and so release the liquid.

Similar letters are used to indicate all similar parts throughout the drawings.

We prefer to enclose the Radiator bodily in a metallic box, closed on all sides, but having an opening in front, the back of the box being preferably mirror-shaped or carrying a separate metallic mirror, and the front hole being either left open or preferably closed with a plate or lens of ebonite, pitch, or other suitable material to assist in rendering the rays approximately parallel, or of concentrating them into a beam.

To further render the beam parallel and cut off more of the diverging rays, so as to prevent them from operating other receivers out of their direct line, we may surround the front hole with a metallic pipe or tube, extending forward for any desired distance, and preferably having its front end closed with an insulating plate, or another lens, and having optionally other lenses in the course of its length. Fig. 2 is a side view of the exterior of the entire projector, shewing the focussing tube at E. The receiving instrument may also be enclosed in a similar box with tube.

The wires of the generating circuit or Oscillator may pass through suitably insulated holes in the back or other part of the metallic screen or projector box. The projector we place in such position as to project or concentrate as much as possible the beam or bundle of rays on to the Receiving Station. Or the Radiator may, in some cases, be used alone without any metallic projector-box and its outer charging knobs may be connected through condensers or otherwise to pipe systems or to earth, or one connected directly to earth and the other to an insulated surface, preferably elevated in the atmosphere. Or, and preferably, another separate pair of balls or knobs may be placed near the ends of the Electrodes A A as shown at F F in fig. 7, and these, instead of the charging knobs themselves, be connected via condensers or otherwise to pipe systems, to earth, or one directly to earth and the other to the elevated insulated surface. The second pair of balls are then preferably placed at such distance that they are not sparked into, together with each charging spark, passing from the charging knobs into the Electrodes A A, but a spark is precipitated into them by the more violent disruption occurring every time a spark passes across between the Electrodes A A. This method has a great advantage in reducing leakage, but they may also be placed closer if preferred and charged together with the main electrodes.

In the battery, current generator, or primary circuit (where an induction coil is used) at the Transmitting Station we place a Morse or other Key convenient for signalling, so as to produce the waves intermittently in the form of dots and dashes. Or we may cause the signalling key, by means of a light long range arm or similar discharger, to open and close a short circuit across the secondary circuit of the induction coil, or of the poles or Electrodes of the high tension machine where such is employed for producing the charge, or to make and break the direct high tension circuit itself. A suitable construction for the key when used in this way is shewn in Fig. 3, wherein K is the Key, and L L Knobs communicating with the high tension electrodes. Or the key may operate a metallic screen, capable of covering part or all of the opening in front of the poles of the Oscillator, thereby alternately shielding and exposing the beam or pencil of rays from or on to the distant station, as shewn in Fig. 4, wherein M is the Key or operating handle, and N the screen.

At the Receiving Station for detecting the radiant energy we then provide a second oscillating circuit connecting inductive surfaces, or a road along which electric surgings can take place, or a metallic loop, open or closed, and in either case preferably synchronised as nearly as possible to the generating oscillating

*Improvements in Means of Telegraphing or Telephoning without Wires.*

circuit or radiator, and having in its path a "Lodge" Coherer, or set of loose contacts, or other light loose contact, through which a battery current is tending, the path of said battery current continuing on, either directly through the electric signalling instruments desired to be worked, or else through a relay or other similar instrument, capable of operating a local circuit in response to variations of resistance in the Coherer or set of loose contacts, produced by the varying impact of the Hertzian or Electric waves. A vibrator, operated mechanically or electrically, is also applied to the Coherer to continually restore its normal equilibrium or resistance after the latter has been changed by the impact of Electric waves.

- 10 We do not limit ourselves to any particular form of light contact for the Coherer but we prefer to employ a tube, made of glass, ebonite or other insulating material, shown in Fig. 5 at O O, with stout conducting Electrodes, P P, sealed or otherwise fixed in, which Electrodes may terminate inside as either stout rods or tubes (shown in the latter form at R R) extending near together, the remaining space in the tube being loosely filled with the conducting granules, or cohering contacts S and the air preferably exhausted to a very low tension, say through a small tubu-

15 lature as T, the tube being then hermetically sealed. The outwardly extending rods from the tube may have tubular conductors U U sliding on them and terminating in balls or other collecting or inductive surfaces. The object of the telescopic slides is to tune the receiver or adjust its rate to that of the Transmitting Oscillator when used for short distance work, or for longer distances the conductors may be connected to other extensions or circuit arrangements, or to pipe-systems, or to earth, or to insulated systems of collecting points placed at an adjustable distance apart, or one pole to such system and the other to earth, and for these connections, both from the Transmitting Radiator (or additional sparking knobs near same) and Receiving Coherer, we find broad strips far better than ordinary round wires, as possessing less self-induction and therefore offering far less impedance to the passage of the rapid electric surging, or oscillating currents. The strips should be well insulated except when connected

- 30 to earth. Any metallic granules will answer, but we find the most effective consist of very fusible metals or alloys, the effect of cohering appearing to consist of a minute fusing together of the contact points or surfaces. For most signalling purposes, therefore, we prefer to use granules of soft solder, lead or tin, or alloys of lead and tin, with or without Bismuth or Cadmium or all together. For other purposes, however, we find Carbon granules very effective, especially when the Telephone is used as the receiving instrument as herein-after described.

35 V Fig. 5 shows the restoring vibrator consisting of an electro-magnet W and ordinary make and break contact X all enclosed in a tight metal box, Y, which may have extending tubes to enclose the battery wires. The armature pivot z extends through the box and carries the rod of a light tapper D, arranged to vibrate against the Coherer tube O. Or any other form of vibrator may be used and it may shake the Coherer in other ways without directly tapping it.

Another form of Receiver, which we sometimes use, is shown at Fig. 6 and consists of the proper collectors and conductors E E formed of metallic strips or rods terminating in balls, or other suitable Electrodes, (the system being tunable for short distance working by bending the extremities more or less near together) or which strips or rods may be connected for longer distance working as above described with reference to the alternative granule tube, and the approaching ends being fixed to an insulating block G and bridged across by a very thin piece of wire H, preferably platinum or aluminium, bent tripod fashion, so as to rest lightly on three points, two being preferably on one Electrode and one on the other. The cohering contact surfaces and wire may also be covered by a suitably packed glass or other bell cover J, from which the air may be exhausted, as by a closable tube through the block G underneath, or otherwise. A vibrator V is also mounted preferably on the same base to restore the equilibrium. Fig. 7 is a diagram of connections of the complete set of Trans-

*Improvements in Means of Telegraphing or Telephoning without Wires.*

mitting and Receiving Apparatus, the electrical connections shewn in full lines being arranged for ordinary signalling and working, say, on a Morse Sounder or Printer. The connections shewn in dotted lines relate to another requirement to be described further on and should be ignored when considering plain Morse signalling only. In this figure the spirals lettered I represent the generating 5 induction coil and *g* its make and break contact with preferably a condenser *h*. *a* represents the signalling Key at the Transmitting Station. A A, B and C C represent respectively the same parts as indicated by similar letters and described in reference to Fig. 1. F. F. are the pair of additional knobs for connecting respectively to elevated surfaces and to earth or to other arrangements as already 10 described, and Q Q, P P, U U represent the receiving Coherer and V the vibrator as described in detail with reference to Fig. 6. *b* represents the relay and *c* the Morse Instrument, both of which may be of any ordinary form, and the latter either a Sounder or Printer. The shunt roads lettered *r* shewn across the Electro-magnets of the Morse Instrument and relay in Fig. 7 and of the Vibrator in 15 Fig. 5 represent ordinary spark shunts or condensers which it is desirable to place across the Electro-magnets of all Instruments required in the vicinity of the receiving Coherer.

For certain purposes of signalling we also find it useful to produce the electric waves at the Transmitting Station in certain rated beats or series of impulses, so 20 that, on the local circuit at the Receiving Station, being affected harmonically, in this rate, certain definite signals may be picked out and given from a series of possible signals operated by the same local circuit.

For this purpose we prefer to use the apparatus described in Patent Specification, No. 7773 of 1884, or other similar arrangements. 25

The Transmitting Pendulums or Reeds then take the place of or are used in conjunction with the Signalling Keys described above, at the Transmitting Station (operating as the Keys, but isochronously, to either open and close the electric circuit or to oscillate a screening shield) and the electro-magnetic Receiving Reeds 30 or Pendulums being included in the local circuit at the Receiving Station, so as by their respective accumulation or interference to pick out and make the proper desired signals. A method of applying such synchronised vibrators, for both Transmitting and Receiving, is indicated by the dotted lines in Fig. 7, wherein on the transmitting side of the diagram *i* represents the transmitting pendulum or reed or its equivalent, the full line connection between the points *d* and *e* being now 35 considered as broken, and the Key *a* being optional may be replaced by the direct connection *f*.

On the receiving side of the diagram *k k* represents in a typical form two of any number of the synchronised reeling pendulums or reeds (but of which any ordinary kind may be used) with their proper connections and *m* an electric bell 40 or other signalling device arranged to be put into action locally by the synchronised vibrators.

As will be seen from the dotted connections the electro-magnetic coils of the synchronised vibrators now replace those of the Morse or other Telegraph Instrument which are now considered as absent, and a local current is applied to the bell 45 or signal on the accumulation or effective operation of any of the synchronised vibrators, or the vibration of the latter alone (or of their equivalents) may also of course for some purposes suffice to make the signals.

This method of signalling is especially adapted and advantageous for Fire and Police Alarms and other Municipal Telegraphs, and is also useful for many other 50 purposes.

For Telephoning we may place a Telephone Transmitter in the primary, or battery, or generator circuit at the Transmitting Station, either in place of or as a shunt for or in series with, the ordinary make and break *g* of the induction coil indicated at I Fig. 7, which make and break should then be rapid. Or (as shewn 55 in Fig. 8) we may employ a moving shield *n* connected to a diaphragm and having a slit or slits to alternately expose more or less of the radiation emerging from a

*Improvements in Means of Telegraphing or Telephoning without Wires.*

similar slit or slits in a fixed metallic shield otherwise then completely, or nearly completely covering the front of the projector box *p*, containing the electrodes of the electric wave generating apparatus, so as to successively vary the intensity of the radiation in response and in proportion to sound waves thrown upon the diaphragm.

In both these cases it is desirable for the vibrating make and break in the primary circuit of the generating induction coil to be of high rate, and the transmitting oscillator circuit designed to give a considerable number of oscillations for each break, as, for instance, by connecting across by a loop of wire of some length the Electrodes *A A* of the transmitting radiator shown in Fig. 1 or its equivalent, whereby it is less damped, although rendered less powerful, so that the received stream of energy shall be as continuous as possible, subject to the varying mechanism described above.

At the Receiving Station for reproducing or rendering the varying rays re-apparent as sound waves we may use any substance, or set of loose contacts, which will vary its, or their, electrical resistance, or resistances, in response to the impact of such radiation, (when properly collected and concentrated thereon, as herein-before described with reference to the Receiving arrangements for Telegraph Signalling) placed in the circuit of a Battery and suitable Telephone Receiver. This arrangement is shown in Fig. 9 wherein *s* is the Coherer or tube containing loose contacts of the desired substance, and which Coherer may be constructed similarly to Fig. 5. This arrangement can also be used for receiving conventional signals, as produced by the operations of the Morse Key, depicted in Fig. 7 in the transmitting part of the apparatus. We find that a Telephone Receiver used in this way, in conjunction with a Coherer, having preferably but not necessarily, carbon granules, forms a very sensitive receiving set for detecting very weak radiant energy as when coming from a long distance *etc.*, because the Telephone is able to appreciate far more minute and temporary (but sudden) changes in the resistance of the Coherer than are required to vary a battery current sufficiently to operate any other telegraphic instrument. Used in this way also no rectifying vibrator is required for the coherer, or at most only an arrangement to give a few momentary taps at long intervals, but this can be conveniently done by hand. Or instead of the Receiving Telephone being in direct circuit with the Coherer it may be connected across the secondary of an induction coil, whose primary is included in the battery and coherer circuit.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, We declare that what We claim is

1. A transmitting radiator of Electric energy, consisting of a pair of elongated rods, having their ends opposed to one another, and either inclined upwards at an angle, or else curved in a somewhat crescent shape, so that in either case the bulk of their surface, and especially their opposed ends, may be and are immersed in oil or other insulating liquids, contained in an electrically insulating vessel, while their opposite ends project out of said liquid conveniently for being charged by sparks sent across from knobs or Electrodes opposed thereto and connected to a source of high potential electricity, as and for the purposes above described.

2. A receiving Coherer, arranged as above described, advantageously for detecting electric radiation and consisting of a tube or vessel containing between or in contact with the Electrodes of the collecting conductors granules of very fusible metals or alloys as above enumerated and to accomplish the above-mentioned objects.

3. The use and employment for the purpose of confining a stream of electric radiation within narrow limits and so preventing it from operating other receivers not intended to be operated thereby, or for the purpose of picking out more closely and responding to the radiation coming from one better defined point only, a metallic tube extending out from the front and surrounding a hole in an otherwise

*Improvements in Means of Telegraphing or Telephoning without Wires.*

closed metallic box containing the radiation producing device or the radiation receiving device respectively, as and for the purposes above described.

4. Where an electro-magnetic vibrator is used to tap back or restore the normal equilibrium of resistance of a Coherer after its having been changed by electric radiation; the use and employment of a metallic box or case to cover in and enclose the said vibrator entirely with the exception of the projecting tapping hammer, or an axle on which this may be mounted, for the purpose of screening the radiation generated by the vibrator away from the receiving Coherer.

5. An electro-magnetic vibrator fulfilling the conditions mentioned in claim 3. above, and constructed as above described and illustrated in Fig. 5.

6. The use and employment in conjunction with an oscillator or radiator of electric energy of a second pair of knobs opposed to the main pair of Electrodes or surfaces, between which the oscillating currents or electric surgings are set up, and connected to pipe-systems, or earth, either with or without the interposition of condensers, or one to earth and the other to a radiating surface, preferably elevated in the atmosphere. Or the use of one separate knob, so connected, in conjunction with an earth connection or a connection to another of the above-mentioned systems, applied to the opposite charging knob.

7. The use and employment for the purpose of connecting the charging knobs or the surface of an Electric Radiator, or other knobs inductively opposed to them, to earth, or to other systems for increasing the radiation, of a conductor composed of a broad strip instead of a round wire, as heretofore used, as and for the purposes above described.

8. The combination with an induction coil or other high tension electric generator and an oscillator or radiator of electric energy, of Reeds or Pendulums for opening and closing the circuits of the induction coil or generator isochronously, or otherwise producing the rays intermittently, or of alternately exposing and shielding a beam of them, in an isochronous rate, for the purpose of actuating tuned or synchronous electro-magnetic Reeds or Pendulums, placed in the receiving circuit.

9. The combination with a Coherer, granule tube or loose contact system used for the purpose of detecting electric radiation of one or more synchronised electro-magnetic Reeds or Pendulums for the purpose of picking out a signal or one of a set of signals made by one transmitter without responding to others which may be acting simultaneously or successively, as and for the purposes above described.

10. The use and employment of a Telephonic Transmitter or Microphone in place of the ordinary make and break, or as a shunt for or in series with a rapidly vibrating make and break of the primary circuit of an induction coil used for producing Hertzian waves or high rate electric radiation capable of operating a receiver at a distance, as and for the purposes above described.

11. The means above described of varying the intensity of a very rapidly produced set, or nearly continuous stream of electric waves by means of a slotted screen covering and uncovering similar slots in a fixed screen in front of the electric projector, proportionately to sound waves thrown upon a diaphragm actuating such screen as and for the purposes above described.

12. The combination with a Coherer or set of loose contacts used for detecting electric radiation of a battery and telephone placed in the same circuit, whether the said telephone is used to re-produce speech or other sounds, or only conventional signals, as and for the purposes above described.

13. In a receiving set used for the purpose of reproducing signals or sounds from a varying stream of electric radiation, the combination of a Telephone, Induction coil, battery and Coherer, or set of loose contacts, the Telephone being connected to one coil, say the secondary, of the Induction coil and the other coil, say the primary, being connected in circuit with the Battery and Coherer or set of loose contacts.

14. Where a Telephone is used in conjunction with a Coherer or set of loose contacts and Battery as a receiving set for detecting and responding to variations of

N<sup>o</sup> 28,955.—A.D. 1896.

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*Improvements in Means of Telegraphing or Telephoning without Wires.*

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electric radiation, the use and employment for the purpose of such Coherer or set of loose contacts of granules or subdivided particles composed of carbon.

15. The use and employment of a pointed conductor, or of a system of points projecting into the atmosphere and connecting to an apparatus for either transmitting or receiving electric waves.

Dated this 15th day of September, 1897.

(Signed.)

A. C. BROWN.  
GEO. R. NEILSON.

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Redhill Printed for Her Majesty's Stationery Office, by Malcomson & Co., Ltd.—1898.

[This Drawing is a reproduction]

at a scale of

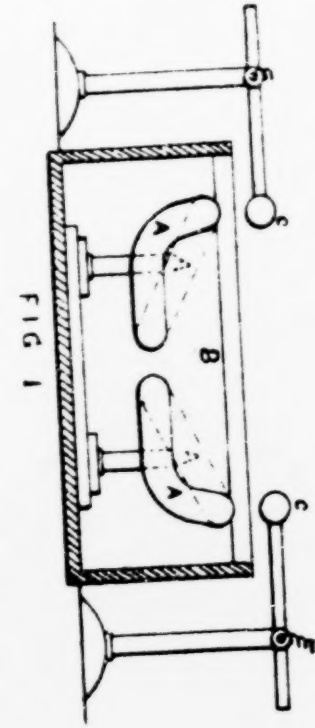


FIG 1

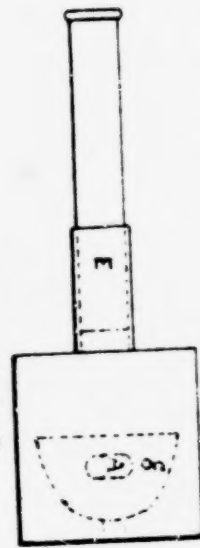


FIG 2

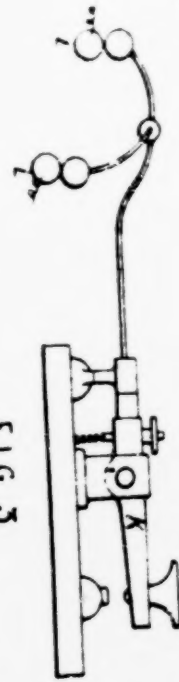


FIG 3

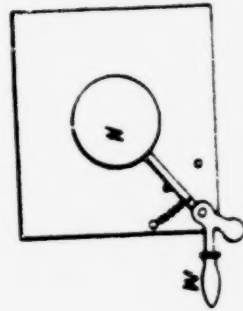


FIG 4

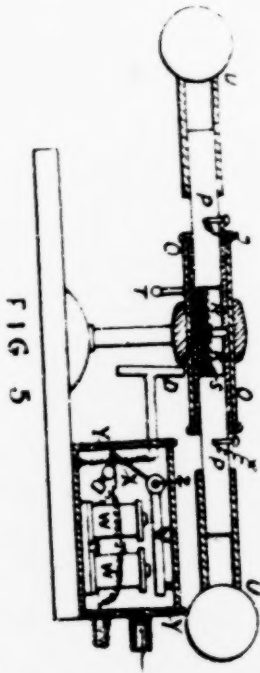


FIG 5

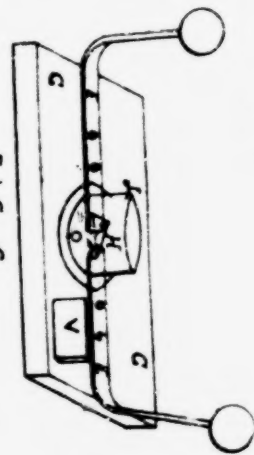


FIG 6

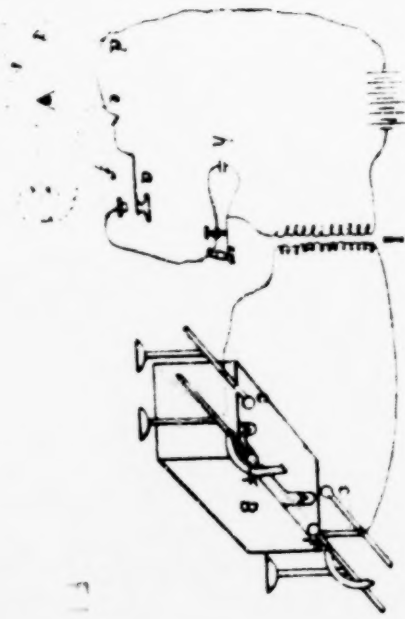


FIG 7

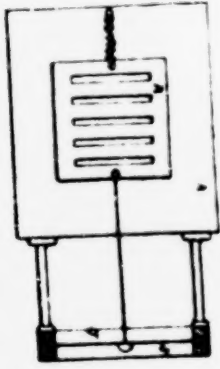


FIG 8

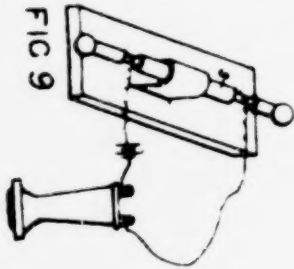
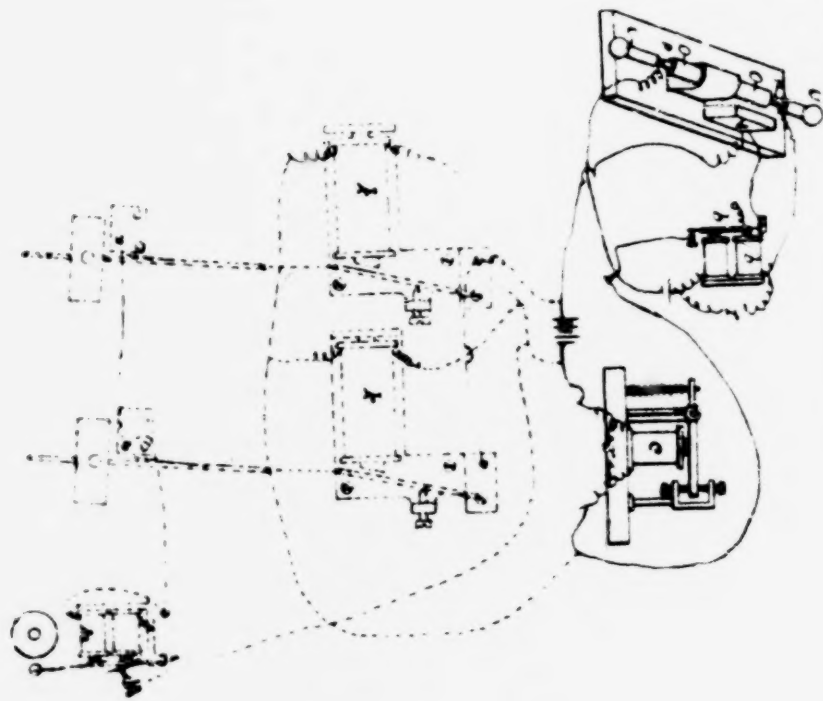


FIG 9



## PLAINTIFF'S EXHIBIT 287

## BRITISH PATENT

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N° 13,518.—A.D. 1908.

*Improvements in Instruments for Detecting Electric Oscillations.*

other plate of this condenser with the sliding contact on the resistance across the glow lamp battery terminals. In this circuit I also include a telephone or current detecting instrument. A current then flows from the battery through the filament rendering it incandescent and also in virtue of the emission of negative electricity from the filament a current flows from it through the vacuum space to the metal cylinder and through the telephone or other current detector. The conductivity of this vacuum space or ionised rarefied gas is a function of the electromotive force acting to drive the current through it. I find that if the position of the sliding contact on the resistance across the terminals of the battery is so adjusted that corresponding thereto the conductivity curve of the ionised gas has a very sudden change in curvature, the superposition of an oscillatory potential difference between the filament and cylinder upon the steady potential difference causes very sudden changes in the current strength through the telephone and therefore an emission of sound.

The arrangement described is therefore a very sensitive detector of oscillations in the condenser circuit to which the glow lamp is attached and therefore can serve as an electric wave detector in inductive or radiotelegraphy, since the sound in the telephone or indication of the equivalent current detector can be controlled from the transmitting end and cut up into Morse or other signals as required, to transmit by electric waves or magneto electric induction intelligence to a distance.

Dated this 25th day of June, 1908.

J. A. FLEMING.

## PROVISIONAL SPECIFICATION.

No. 26,832, A.D. 1908.

## "Improvements in Instruments for Detecting Electric Oscillations."

I, JOHN AMBROSE FLEMING, of University College, Gower Street, in the County of London, Doctor of Science, do hereby declare the nature of this invention to be as follows:—

My invention has reference to that type of electrical oscillation detector described by me in a British Patent Specification No. 24,850, of November 16th 1904, entitled "Improvements in instruments for detecting and measuring alternating electric currents."

According to this invention I employ a carbon cylinder as the cold conductor in the vacuum bulb in place of the metallic cylinders heretofore employed.

Dated this 10th day of December 1906.

J. A. FLEMING.

## COMPLETE SPECIFICATION.

## "Improvements in Instruments for Detecting Electric Oscillations."

I, JOHN AMBROSE FLEMING, of University College, Gower Street, in the County of London, Doctor of Science, do hereby declare the nature of this

N<sup>o</sup> 13,518.—A.D. 1908.

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*Improvements in Instruments for Detecting Electric Oscillations.*

invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement:—

My invention has reference to that type of electrical oscillation detector described by me in a British Patent Specification No. 24,850 of November 16th 1904, entitled "Improvements in instruments for detecting and measuring alternating electric currents."

In this specification I described an oscillation detector subsequently called an oscillation valve or glow lamp detector, which consists of an electric glow lamp of the ordinary type, but having within the glass bulb a metal plate or cylinder carried on an insulated terminal sealed through the glass. When the filament is rendered incandescent by an electric current, it emits negative ions or corpuscles or electrons and these ionise the residual gas in the bulb, and give to the space a unilateral conductivity by which negative electricity can pass from the hot filament to the cold insulated plate or cylinder within the bulb, but not in the opposite direction. I employed this device as an electric wave detector in radiotelegraphy by connecting the insulated plate or cylinder to one terminal of an oscillation transformer inserted in the receiving circuit of the radiotelegraphic apparatus, and the other terminal of this oscillation transformer was connected through a galvanometer or telephone to the negative terminal of the filament.

I have discovered after many experiments that tungsten in various forms and particularly in a form in which it is employed as the filament in a glow lamp is highly efficient for this purpose, since the amount of negative electricity emitted at the highest possible working temperature may be from 10 to 20 times as great as that emitted by carbon in an ordinary carbon filament. I am unable to explain the reason of this superiority; it is not merely that a tungsten filament can be raised to a higher temperature than a carbon filament, for metals such as tantalum which are closely analogous to tungsten and which can be raised to an equally high temperature are not much superior to carbon at any temperature at which they can be worked in practice.

I find that a cylinder of carbon acts better as the cold conductor in the bulb than a metallic cylinder.

I construct such a metallic or semi-metallic filament glow lamp with a tubular glass bulb and a cylinder of carbon sealed into the bulb, surrounding but not touching the filament, and connected to a platinum wire sealed through the glass. Furthermore, I employ this glow lamp as an oscillation detector as follows:—The filament is rendered incandescent by an insulated battery having in series with it a rheostat or variable resistance for controlling the current. Across the terminals of this battery I place another high resistance having a sliding contact in it, so as to make contact with any desired point on this resistance. In using this detector in wireless telegraphy the receiving circuit must comprise a closed circuit having inductance and containing a condenser. If the telegraphy is conducted by electric waves it is necessary also to connect an antenna either directly or indirectly with this condenser circuit. I then connect the insulated cylinder included within the bulb of the lamp with one plate of the condenser in the oscillation circuit, and I connect the other plate of this condenser with the sliding contact on the resistance across the glow lamp battery terminals. In this circuit I also include a telephone or current detecting instrument. A current then flows from the battery through the filament rendering it incandescent, and also in virtue of the emission of negative electricity from the filament a current flows from it through the vacuum space to the metal cylinder and through the telephone or other current detector. The conductivity of this vacuum space or ionised rarefied gas is a function of the electromotive force acting to drive the current through it. I find that if the position of the sliding contact on the resistance across the terminals of the battery is so adjusted that corresponding thereto the conductivity curve of

*Improvements in Instruments for Detecting Electric Oscillations.*

the ionised gas has a very sudden change in curvature, the superposition of an oscillatory potential difference between the filament and cylinder upon the steady potential difference causes very sudden changes in the current strength through the telephone and therefore an emission of sound provided that the steady potential difference is of the necessary critical value. 5

The arrangement described is therefore a very sensitive detector of oscillations in the condenser circuit to which the glow lamp is attached and therefore can serve as an electric wave detector in inductive or radiotelegraphy, since the sound in the telephone or indication of the equivalent current detector can be controlled from the transmitting end and cut up into Morse or other signals 10 as required, to transmit by electric waves or magneto electric induction intelligence to a distance.

In carrying my invention into effect, I employ a tubular form of glass bulb *a* which may be an inch or more in diameter and 5 or 6 inches in length. In this I insert a cylinder *b* of carbon which is sprung into the glass tube so as to fit the walls tightly. This cylinder has a platinum wire *c* twisted or welded to it which is sealed through the glass, so as to make an external electrical connection. The bulb *a* should have a good vacuum such as is usually employed with lamps having metallic filaments. 15

The metallic filament *d* is formed of tungsten in the form used as a filament 20 in ordinary glow lamps and is connected to conductors *e* carried on a glass tubular stem *f* sealed into the bulb. The filament *d* should be of such a length that it is entirely covered by the metal cylinder *b*.

It is convenient to have the filament of such length and thickness that the voltage required to bring it to incandescence at which its duration may not be 25 less than several hundred hours, is of the order of 18 volts or so.

In applying this glow lamp as a detector in radiotelegraphy I arrange it as follows:—

A battery *g* of secondary cells is provided which may conveniently be a dozen or more cells, and wires *h* are brought from the terminals of this battery 30 to the terminals *e* of the filament of the lamp, a variable resistance *j* *k* being inserted in the circuit. It is convenient to divide this resistance into two, one namely *j* of from say 0 to 120 ohms being for coarse adjustment and the other *k* of from say 0 to 5 ohms being for fine adjustment. By means of these resistances the current of the lamp may be adjusted to have any required value. 35 A voltmeter *l* should also be placed across the terminals of the filament to regulate the voltage. In addition I place across the terminals of the battery *g* a high resistance *m* of the potentiometer type, that is to say, a resistance which may be two or three hundred ohms or more, the terminals of which are connected to the terminals *h* of the battery. A double high resistance telephone *n* 40 (the resistance of each telephone being at least five or six hundred ohms) has one terminal connected to a slider *o* which can make contact with any required point on the resistance *m* and the other terminal connected to one plate of a condenser *p*. The other plate of the condenser *p* is connected with the metal cylinder of the lamp. The condenser *p* is inserted in a circuit possessing 45 inductance, which is directly or inductively connected with a receiving antenna. As shown the circuit connecting the two plates of the condenser *p* contains an adjustable inductance *q* and the secondary of the jigger *r* the primary of which is in the aerial *s*. When electric waves fall upon the receiving antenna they excite oscillations in the condenser circuit and oscillations are thus imposed 50 upon the telephone circuit connecting the metal cylinder or plate in the lamp with the sliding contact and high resistance connected across the terminals of the battery or other source of continuous electric current.

In operating the arrangement, the first step is to bring the filament to a high incandescence at which it would be working approximately at one watt per candle and at which it will have such a temperature, approximately 2800° C. 55

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that it will diffuse into the vacuous space negative ions discharged from the incandescent filament.

The filament having been rendered incandescent to this temperature, the observer applies the telephone to his ear and if electric wave trains are falling  
 5 upon the receiving antenna *s*, it will be found that on moving the slider *e* along the potentiometer resistance *m* from one end to the other, there is a certain point at which sounds will be heard in the telephone better than at any other point. The exact position of the slider *e* must be determined by trial for it varies with every valve owing to slight differences in the vacuum and tem-  
 10 perature of the filament. The detector above described is suitable as the receiver in radiotelephony, as well as for signals on the Morse or other alphabetic code.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what  
 15 I claim is:—

1. An oscillation valve in which the hot conductor is a filament of tungsten substantially as described.
2. An oscillation valve in which the hot conductor is a filament of tungsten and the cold conductor is a cylinder of carbon substantially as described.
- 20 3. The combination of an oscillation valve, a source of electricity heating the filament of the valve, a resistance across the terminals of the source, a circuit connected at one end to the cold conductor of the valve and at the other to an adjustable point of the resistance, and means for producing oscillations and detecting electric current in the circuit substantially as described.
- 25 4. Instruments for detecting electric oscillations substantially as described and illustrated in the drawing.

Dated this 10th day of December 1908.

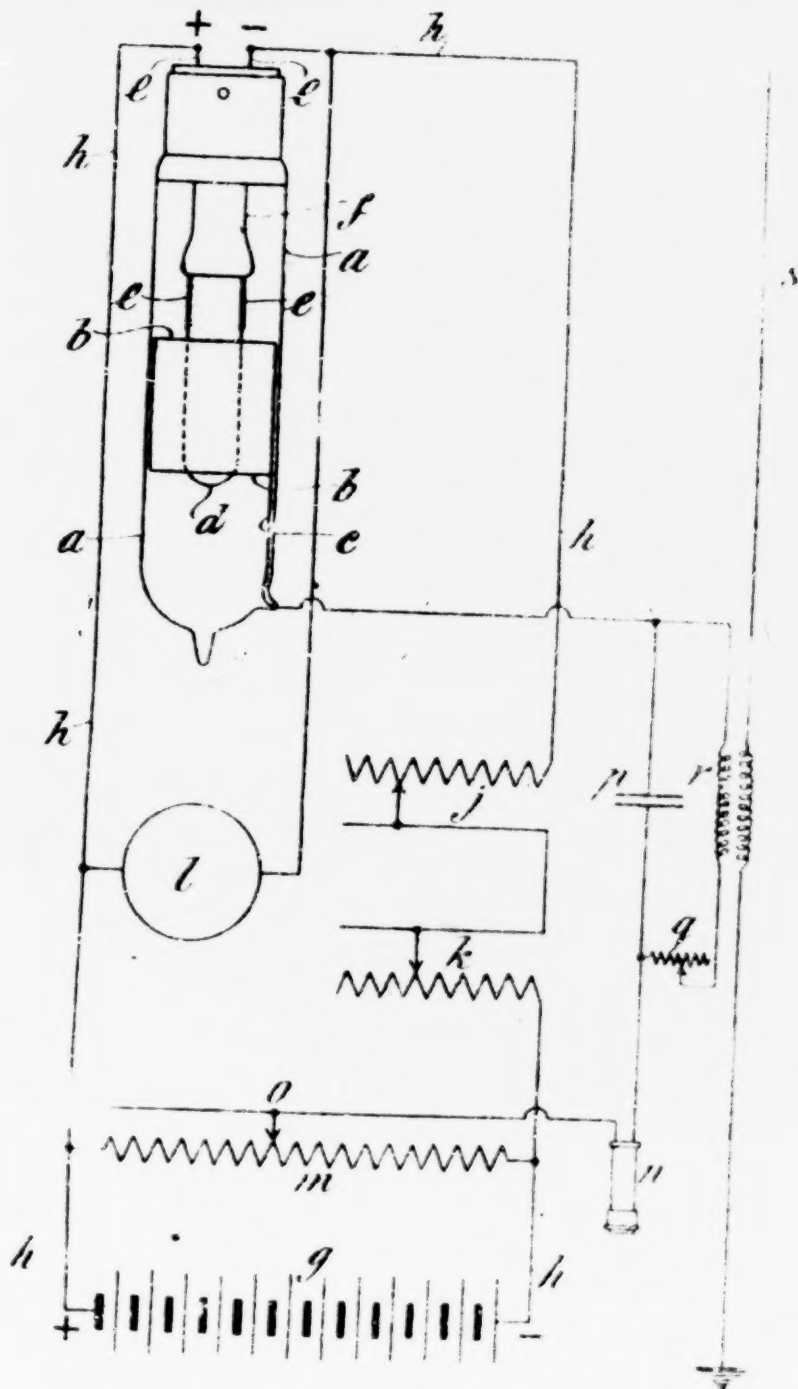
J. A. FLEMING.

## Claimant's Exhibit No. 287

A. D. 1908, JUNE 23, N° 13,518.

FLEMING'S COMPLETE SPECIFICATION.

(1 SHEET)

(2<sup>nd</sup> Edition)

2760

2761

PLAINTIFF'S EXHIBIT 289

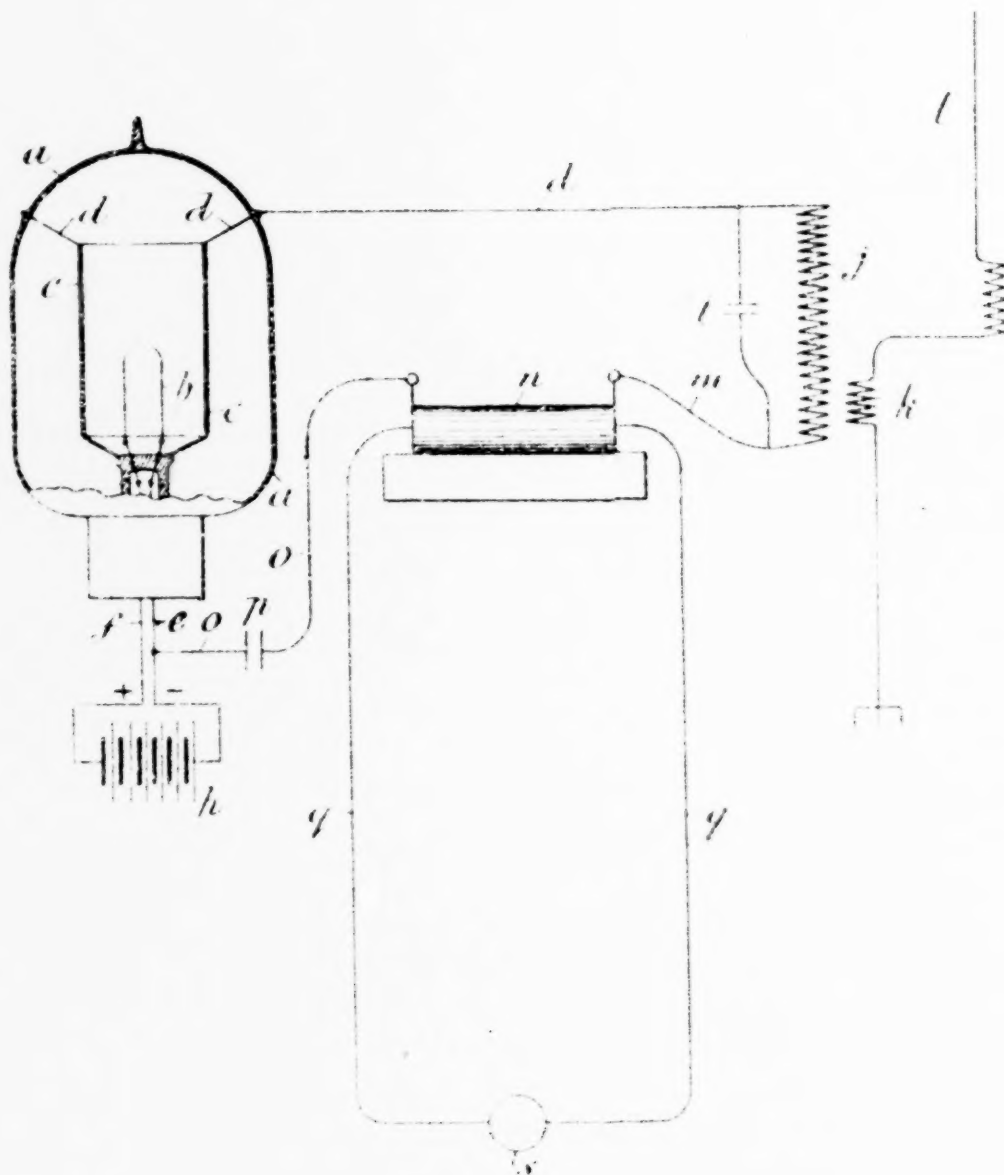
No. 896,130.

PATENTED AUG. 18, 1908.

G. MARCONI.

RECEIVER FOR WIRELESS TELEGRAPHY

APPLICATION FILED MAR 19, 1907.



Witnesses

Edward H. Tait.

Wm. J. F. F.

Inventor  
Guglielmo Marconi  
By  
Samuel R. Betts  
his Attorney

# UNITED STATES PATENT OFFICE.

GUGLIELMO MARCONI, OF LONDON, ENGLAND, ASSIGNOR TO MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA, OF NEW YORK, N. Y., A CORPORATION OF NEW JERSEY.

## RECEIVER FOR WIRELESS TELEGRAPHY.

No. 896,130.

Specification of Letters Patent.

Patented Aug. 18, 1908.

Application filed March 13, 1907. Serial No. 362,121.

*To all whom it may concern:*

Be it known that I, GUGLIELMO MARCONI, LL. D., D. Sc., a subject of the King of Italy, residing at 18 Finch Lane in the city of London, England, have invented new and useful Improvements in Receivers for Wireless Telegraphy, of which the following is a specification.

This invention relates to a method of employing the well known Fleming's oscillation valve (described in the U. S. A. specification No. 803,684) in wireless telegraphy. This valve consists of a vacuum vessel having in it two conductors adjacent to but not touching each other one conductor being heated in any convenient manner while the other is connected to an external circuit.

The oscillation valve is preferably placed in shunt with the secondary of the step-down transformer or jigger, which is, as usual, connected with the aerial. The circuit including the secondary coil of the jigger and the oscillation valve, also includes the primary or fine wire winding of the induction coil or step-down transformer, the secondary winding of which is connected with a telephone receiver, relay, or other suitable wave responsive device for detecting the received signals.

A condenser *r* may be placed in series between the valve and the induction coil and a second condenser in a shunt across the ends of the secondary of the jigger.

The condenser last mentioned, together with the secondary winding of the jigger, forms a closed oscillatory circuit when the capacity of this condenser is properly adjusted for syntonism.

The values of the inductance and capacity of the transformer or jigger and the value of the capacities of the condensers associated to it should be such as to bring the receiving circuit, including said jigger into resonance with the period of the transmitted oscillations.

The drawing is a diagram of the arrangement it is preferred to adopt.

*a* is a glass bulb, and *b* is a carbon filament like the carbon filament of an incandescent lamp, suitable say for taking a current of 6 to 8 volts and 2 to 4 amperes. *c* is a cylinder of aluminum open at the top and bottom which surrounds but does not touch the filament. The cylinder *c* is suspended and steadied by platinum wires *d*, and the ends of the filament

*b* are connected to platinum wires connected to the leads *e* and *f*. The platinum wires are sealed through the glass in the ordinary manner. *h* is a battery by which the filament *b* is heated. This arrangement is one form of the oscillation valve described in the said former specification.

One of the wires *d* is connected to the secondary *j* of the jigger the primary *k* of which is connected to the ordinary aerial *l* and to earth. The other end of the secondary *j* is connected by a wire *m* to one end of the fine wire winding of an induction coil *n* (which should be such as usually manufactured to give say a 10 inch spark) the other end of its fine wire winding being connected by a wire *o* through a condenser *p* to the lead *e*. When the induction coil is thus connected, the fine wire winding, usually operating as a secondary winding, becomes the primary coil, while the coarse wire winding, usually operating as the primary winding, becomes the secondary coil. The ends of the secondary of the coil *n* are connected to a circuit *q* containing a detector *s* of any ordinary type such as a telephone or a relay operating a printing instrument. *t* is a condenser in a shunt across the secondary *j* of the jigger.

By using a condenser, such as the condenser *t*, in the resonant circuit, the receiving circuit not only may be more easily brought into syntonism with the received oscillations, but such condenser permits the oscillations in the resonant circuit to accumulate to such an extent that their electromotive force is sufficient to overcome the resistance of the space between the filament *b* and the cylinder *c* in the oscillation valve, thereby increasing the strength of the waves rectified by said valve. Inasmuch as the electromotive force of the oscillations rectified by the oscillation valve is high, while its current value is small, the induction coil *n* transforms the current so that it acts upon the detecting device as one of lower potential and higher current value. These conditions are, therefore, the reverse of those usually found in detectors for electromagnetic waves heretofore used.

Inasmuch as the fine wire winding of the induction coil *n* introduces a large amount of inductance into the receiving circuit, the condenser *p* is introduced to counteract the same.

The pulsating current produced in the

parts of the receiving circuit comprising the filament *b*, the wire *e*, the wire *d*, the condenser *f*, the fine wire winding of the induction coil *h*, and the wire *m*, results in an alternating current in the wires *g* and the detector *s*, the latter current being of comparatively large volume and low potential.

The term "aerial" is intended to embrace any conductor in which oscillations are set up by the incoming Hertzian waves.

What I claim is:

1. In a receiving apparatus for wireless telegraphy, the combination with an oscillatory circuit, of an oscillation valve, an induction coil, the oscillation valve and the primary winding of the induction coil being connected in series and operatively connected with said oscillatory circuit, and a detecting device connected with the secondary winding of said induction coil.

2. In a receiving apparatus for wireless

telegraphy, the combination with an oscillatory circuit including a condenser, of an oscillation valve, an induction coil, the oscillation valve and the primary winding of the induction coil being connected in series with each other but in shunt with said condenser, and a detecting device connected with the secondary winding of said induction coil.

3. In a receiving apparatus for wireless telegraphy, the combination with an oscillatory circuit, of an oscillation valve, an induction coil and a condenser, said valve, condenser and the primary winding of the induction coil being connected in series and operatively connected with said oscillatory circuit, and a detecting device connected with the secondary winding of said induction coil.

GUGLIELMO MARCONI.

Witnesses:

ROBERT B. RANSFORD,  
ARTHUR CARPMAEL, Jun.

## PLAINTIFF'S EXHIBIT 290

## VACUUM TUBE AS AN OSCILLATION GENERATOR 269

The same considerations apply to the mutual conductance which can be taken approximately to be equal to the slope of the line joining the extreme point of the characteristic over which the operation takes place.<sup>1</sup>

The problem of setting up the conditions for oscillation, therefore, reduces to the solution of a network involving the oscillation circuit,  $LCr$ , a fictitious generator giving a voltage equal to  $\mu e$ , and a resistance  $r_p$ , as defined above. By adopting this procedure, we do not entirely ignore the curvature of the characteristic. If the resistance  $r_p$  were not dependent on the intensity

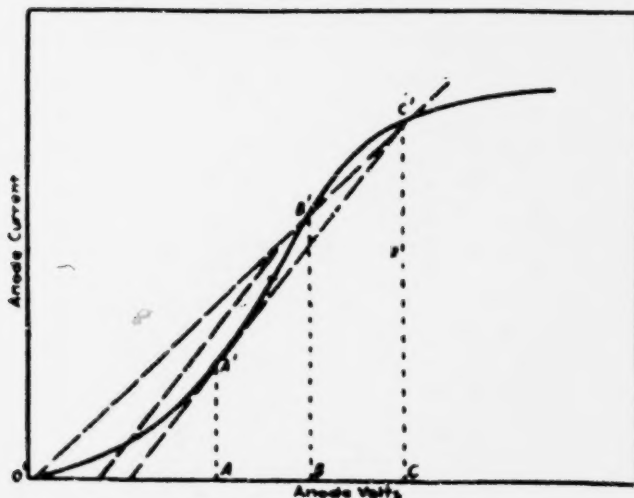


FIG. 150.

of the oscillations, the solution of the network involving the quantities enumerated above would not give an indication of the amplitude of the oscillations; however, both  $r_p$  and the mutual conductance  $g_m$  are dependent on the intensity of the oscillations. The condition for oscillation will require that  $r_p$  and  $g_m$  have values lying within certain limits, and since their values depend on the extent of the characteristic over which operation takes place, the amplitude of the oscillations will be determined by the shape of the characteristic and the constants of the external circuit.

81. Conditions for Oscillation in a Two-element Device. Let us first consider the simple case of a device containing two

<sup>1</sup> L. A. HAZELTINE, Proc. I.R.E., Vol. 6, p. 63, 1918.

Claimant's Exhibit No. 290

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THERMIONIC VACUUM TUBE

electrodes and having a resistance  $r$ , and see what are the conditions that must be satisfied in order that this device, when connected to an oscillation circuit may produce sustained oscillations. The circuit is shown diagrammatically in Fig. 151. The device is supplied with a direct current by means of the battery  $E$ , through the choke coil  $Ch$ . The oscillation circuit is represented by  $LC$ .

The condition for oscillation in such a circuit can be obtained by the simple process of setting the differential equation for the circuit and equating the damping factor to zero. In doing so we need, of course, only to consider the a-c. circuits, that is, the

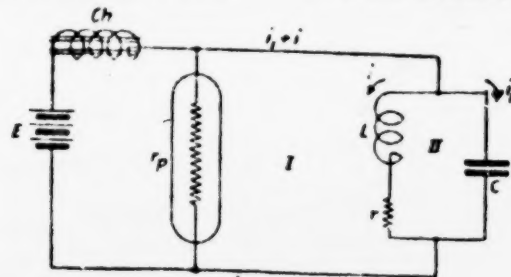


FIG. 151.

two branches I and II. Thus, summing the electromotive forces for circuit I, we get

$$r_p(i_1 + i) + ri + Lpi = 0, \quad (1)$$

where  $p = \frac{d}{dt}$

For branch II we have

$$Lip^2 + rpi = \frac{q_1}{C}. \quad (2)$$

Putting the value of  $i_1$  given by equation (1) into (2) we get:

$$p^2 + \left( \frac{r}{L} + \frac{1}{Cr_p} \right) pi + \frac{i}{LC} \left( 1 + \frac{r}{r_p} \right) = 0. \quad (3)$$

This is an equation of the well-known form from which it follows directly that in order that the current  $i$  shall be oscillatory, the coefficient of the linear term must be zero. That is:

$$r_p = - \frac{L}{Cr}. \quad (4)$$

2765

## VACUUM TUBE AS AN OSCILLATION GENERATOR 271

From this we see that in order to obtain sustained oscillations from a device having only two electrodes, it is necessary that the device shall have a negative resistance. Examples of negative resistances have already been given in the previous pages. Thus an arc may have a negative resistance, its characteristic being of the form shown by the curve *AB* in Fig. 34. The resistance is given by the slope of the characteristic and this is a negative quantity for a characteristic of the kind shown. Fig. 16, page 48, shows another characteristic which over a region *ABC* has a negative slope and is obtained as the result of the emission of electrons from metals under the impact of electrons. Such characteristics as these are sometimes referred to as "falling characteristics."

The thermionic valve does not show a falling characteristic like the curve *AB* of Fig. 34, when it is sufficiently well evacuated to prevent the effects of ionization by collision from appreciably influencing the discharge. The characteristics of thermionic valves are those given and discussed in the previous chapters and it will be seen that for such devices the resistance is always positive. It is, therefore, impossible to obtain sustained oscillations from a well-evacuated thermionic valve containing only two electrodes. If such a device contains an appreciable amount of gas during the operation, the characteristic becomes unsteady and sometimes, especially at the higher voltages, exhibits regions over which the slope is negative, and when operated over that region it is, of course, possible to obtain sustained oscillations. The condition which makes this possible in a two-electrode device is unfortunately due to the cause which makes such a device unsatisfactory; namely, the presence of too much gas in the device, thus causing unsteadiness of the discharge and making reproducibility practically impossible. If a controlling electrode or grid be added to the two electrodes of a valve, the operation becomes different and we now have a device which can produce sustained oscillations with facility while at the same time satisfying all the conditions that are necessary to secure satisfactory operation in every respect, namely, freedom of gas with consequent steadiness and reproducibility of results, and comparatively long life.

### 82. Condition for Oscillation for Three-Electrode Tube.

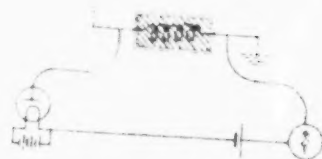
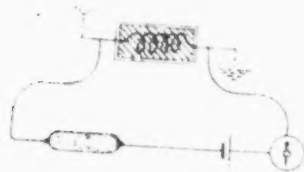
Let us now consider a circuit like that shown in Fig. 152. This is one of a large number of possible oscillation circuits. It is

## Claimant's Exhibit No. 298

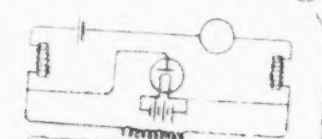
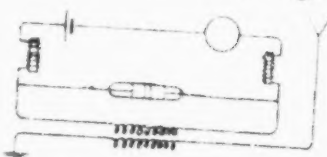
3185

USE OF A LOCAL BATTERY OBVIOUS.

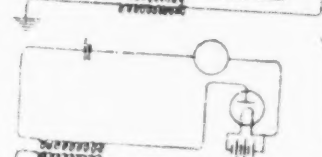
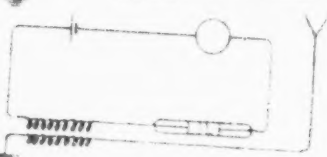
LODGE 609154  
Fig 3



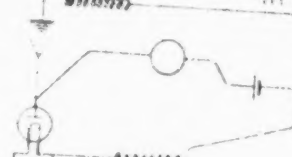
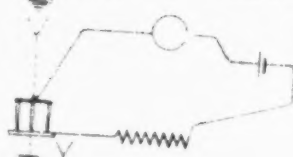
MARCONI 627650  
Fig 1



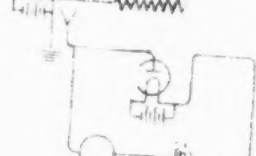
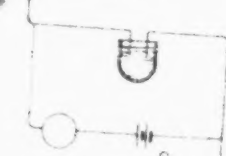
MARCONI 627650  
Fig 2



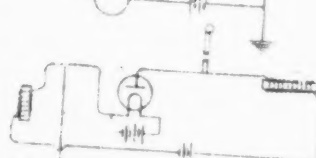
BRANLEY 796800  
Fig 1



LESSENDEN 727331  
Fig 1



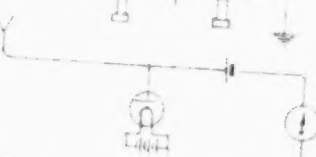
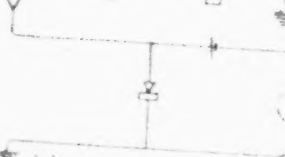
DE FOREST & SMYTH  
716203  
Fig 1



HOGG 763894  
Fig 3



BOST 755840



VRELLAND  
780842  
Fig 4



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# THE ELECTRICIAN:

THE OLDEST WEEKLY ILLUSTRATED JOURNAL OF

ELECTRICAL ENGINEERING, INDUSTRY, SCIENCE AND FINANCE.

~~ITALY 1920, Two Series Early, 1921 Second Series Middle, 1922~~

~~No. 1953 - [REDACTED]~~

**FRIDAY, NOVEMBER 21, 1913.**

**THE**

[illegible]

## NOTES.

— Opening Statement of Testimony —

The lectures which in recent past members of the Institution of Electrical Engineers were told they would enjoy when they became possessed of a house of their own included apparatus lectures delivered by eminent men. What was it but the house because a fact the lecture theatre was provided with suitable equipment for the supply of costumes and stagecraft current in many shapes and forms. And every other preparation was made to render the carrying out of the work as easy as possible. We must, therefore, suppose that the reason the delivery of such lectures has been dropped so long was either that the lecturer or the audience were lacking. Considering that the electrical engineering profession is exceedingly rich in both lecturers and natives to lecture about experimentally, neither of the explanations seems very probable and we must suppose that the true solution is something more sought for the giving of an experimental lecture involves so much that that it is a task not lightly to be undertaken. Speculation as to the points is not, however, very profitable at the present time, considering that the idea was successfully demonstrated Thursday with the delivery of a lecture on

"Electricity" by Mr. W. D. Duane, F.R.S. No better  
 accession or lecturer could have been chosen, not only because  
 it relieved us from a prosaical address of the usual type,  
 but because Mr. DUBUELL, Mr. DUNBAR, is never dull.  
 Moreover, his experiments have an unusual way of coming  
 off, a matter which adds both to the enjoyment of the  
 audience and the *awy-frood* of the lecturer. Mr. DUBUELL's  
 lecture dealt with some interesting points in scientific  
 engineering which are but little understood, and, as will be  
 seen from the account we give on another page of this issue,  
 he has been able to bring together a great deal of informa-  
 tion which has hitherto been scattered. We would particu-  
 larly congratulate Mr. DUBUELL on his water model for  
 illustrating the oscillating nature of the electric arc. It is  
 small wonder, then, that in anticipation the lecture room  
 was full ten minutes before the lecture started, while at  
 ten minutes after eight it resembled the gallery at Crystal  
 Palace on a Circus night. Representatives of all branches  
 of the profession were to be seen, and found the quiet  
 conversancy which took place in the earlier part of the evening  
 it would seem that the only people who did not attend were  
 those to whom premiums were awarded for their work  
 during the past season. This, we feel, is modesty that  
 requires explanation, for if the Council can fit to award a  
 member for his labours, the least he might do is to be present  
 to receive that award. One other remark: To follow a  
 lecture with the eloquence which the subject had Thursday  
 deserved it is necessary that the audience should be com-  
 fortable. The ventilation of the hall made this difficult,  
 and gave rise to the wonder whether, if gas with its sus-  
 posed virtues had been used for lighting, the air would have  
 been any fresher. Perhaps some gas expert will tell us?  
 Nevertheless the evening was most successful, and a fitting  
 prelude to a season when many interesting meetings are to  
 be expected.

### The Auction as a Policy.

In another column of this issue our readers will find a Paper on the sodium, recently read before the Institute of Radio Engineers in New York by Dr. Lee de Forest. We need scarcely say that this detector has been in use for a number of years and that as far back as 1907 Dr. de Forest obtained a patent for its use as a trier. This part of the subject seems to have lain dormant until the present time. Now, however, it appears that the author has done further work in this direction with very interesting results. Briefly, the sodium may be described as a Fleming valve with an additional stroke (which we may designate by B as

distinct from the electrode A in the Fleming valve), the relay circuit being joined to this electrode and to the filament in series with a considerable pressure (15 to 25 volts). When electrical oscillations pass between the A electrode and the filament there is a marked alteration in the current flowing between the B electrode and the filament. This alteration is found to be so marked that it can be used for relay purposes, the relay consisting of two or more audions in series with transformers between them, current from the B electrode of the first being supplied to the primary of a transformer whose secondary supplies oscillations to the A electrode of the second, and so on. By this means an amplification of 120 times has been obtained by using three audions in cascade, and the current thus becomes sufficiently large to operate a moderately sensitive contact relay which, in its turn, can be used to operate a calling device; or the audion may be used with its amplified current in connection with a telegraph. The latter seems to give promise of interesting developments as it provides a simple means of recording. For this purpose it has been used at the new stations of the Federal Telegraph Company, recording messages between San Francisco and Los Angeles, but it is not limited to our stations. Further, there are possibilities that the instrument may be used as a telephone relay. In passing we must remind us have no objection for the name "audion," to which exception was taken at the time it was introduced, and we think that Dr. de Forest might be more generous in his acknowledgment of the work of Dr. J. A. Fleming. Our readers generally will probably agree that the audion, although differing widely from the Fleming valve, is an offshoot of it.

#### The Status of the Engineer.

In his inaugural address to the Dublin Local Section of the Institution of Electrical Engineers last week, Mr. G. MARSHALL HARRIS gave some interesting details of the way in which the medical profession many years ago raised the status of its members and excluded outsiders from its ranks. The obvious deduction is that electrical engineers should go and do likewise. Now, it cannot be denied that at the present time the electrical profession and industry are much too loosely organized. It nominally contains within its ranks many who are not engineers at all, and many whom but of what is right and proper brings discredit on the body as a whole. And though we wish that the state of things might be altered, we feel that what the medical men did in 1859 cannot be taken as a precedent, nor as an example which electrical engineers may profitably follow. The medical profession adopted a course which was the best for them, but we do not think it would necessarily be the best for electrical engineers. There are two reasons for this. In the first place, engineering, especially electrical engineering, is divided against itself, with the result that it would be almost impossible at the present time to draft a bill similar to that of the Medical Act of 1859 on lines with which even a majority of those engaged in electrical work would agree. This statement must not be taken as reflecting on either class; it simply implies that the profession and trade, and also separate branches of

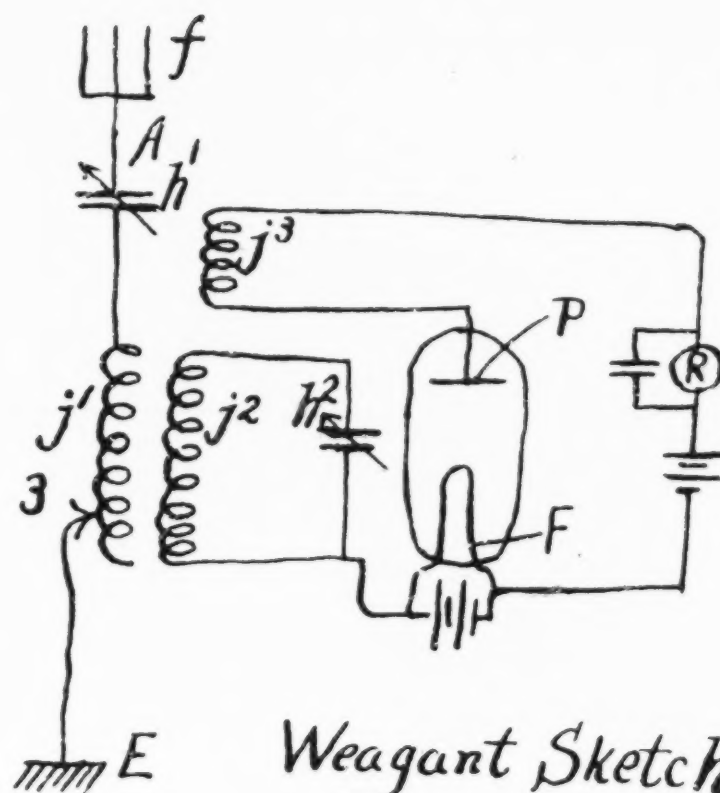
work, have also an irreconcilable opposition to each other, and are therefore liable to quarrel. Another and greater difficulty is that caused by the conditions under which electrical engineering work is carried on. Indeed, it is a difficulty which presents an almost insuperable barrier to electrical engineers following the example of the medical profession.

In the medical profession a practitioner either is a qualified man or he is not. However, the profession is a homogeneous body. It is, therefore, easy to draw a line, and to say that those who are on one side of the line are professionally equal and those who are on the other side are not. This, however, cannot be done with electrical engineering as a whole owing to the presence of many ranks and files. Moreover, in this army, commissioned and non-commissioned officers are often very closely connected, there is one class merging very nearly into that of the other, so that, while it is possible to take one man and say here is a fully qualified engineer, and to take another and say here is a fully-qualified engineer, there are many others whose status is nebulous, with the result that the division between those on one side of the line and those on the other is indeterminate. This being so, it is difficult to say how anybody connected with electrical engineering can be prevented from calling himself an electrical engineer, though, as HARRY PAIR says, "to be an electrical engineer is another matter."

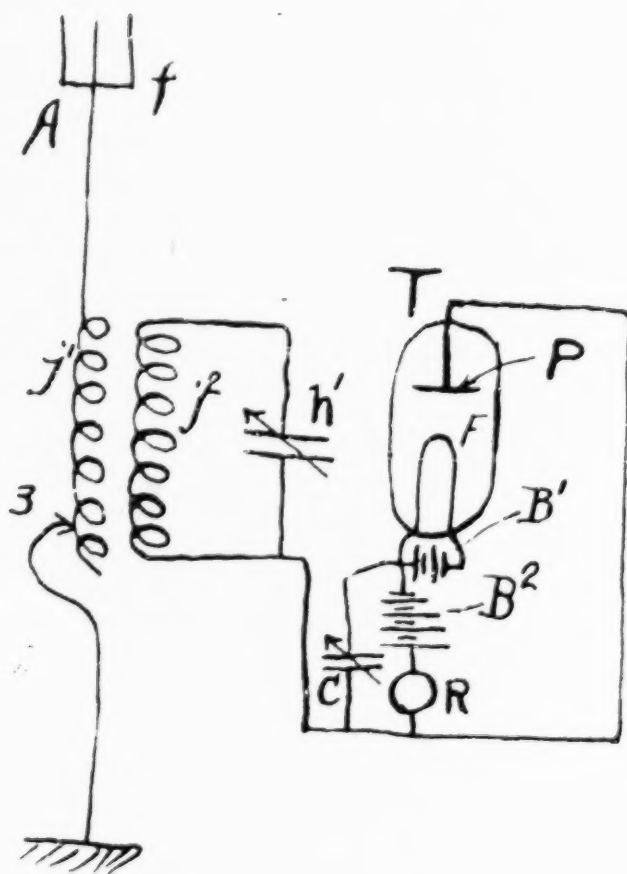
The question is, therefore, a very difficult one, but though it is possible to regulate status among the members of a class, as is being successfully done by the Association of Consulting Engineers, the same procedure cannot be followed throughout the trade, where a man's status cannot be definitely defined. It may be said that the trade unions do what we say cannot be done; but it should be pointed out that, after all, they also only legislate in a single class, and in our view often impose restrictions which are not for the public good. But even if this contention were correct it would not affect our argument, because neither legislation nor consulting engineers are for workers' bodies that very large middle class which profits at the present time must require adjustment. And it is less likely that legislation must fail, for a while at least, to be effective. It rather requires that every man should put his own work in accordance with the highest principle, and with the purest ethical aim, so that electrical engineering may be reformed from within and the chaos checked.

**NEW PLANT.**—An interesting film of the first air-plant was shown this week at the Rialto Picture Palace. This plant has been laid down in Egypt for irrigation purposes, and consists of five long oval cylindrical mirrors, which concentrate the rays of the sun on a small iron boiler in the top of a pipe running along the axis of the cylinder. The mirrors are automatically turned by a thermometer to reach the sun rays to the maximum extent. This plant is capable of using 1,000 lb. of steam per hour. Owing to the high cost of fuel the tropical there is said to be a great saving with this type of plant. The mirrors are 300 ft. long and are covered with glass. It is estimated that 250 h.p. can be obtained for over one

## Claimant's Exhibit No. 301

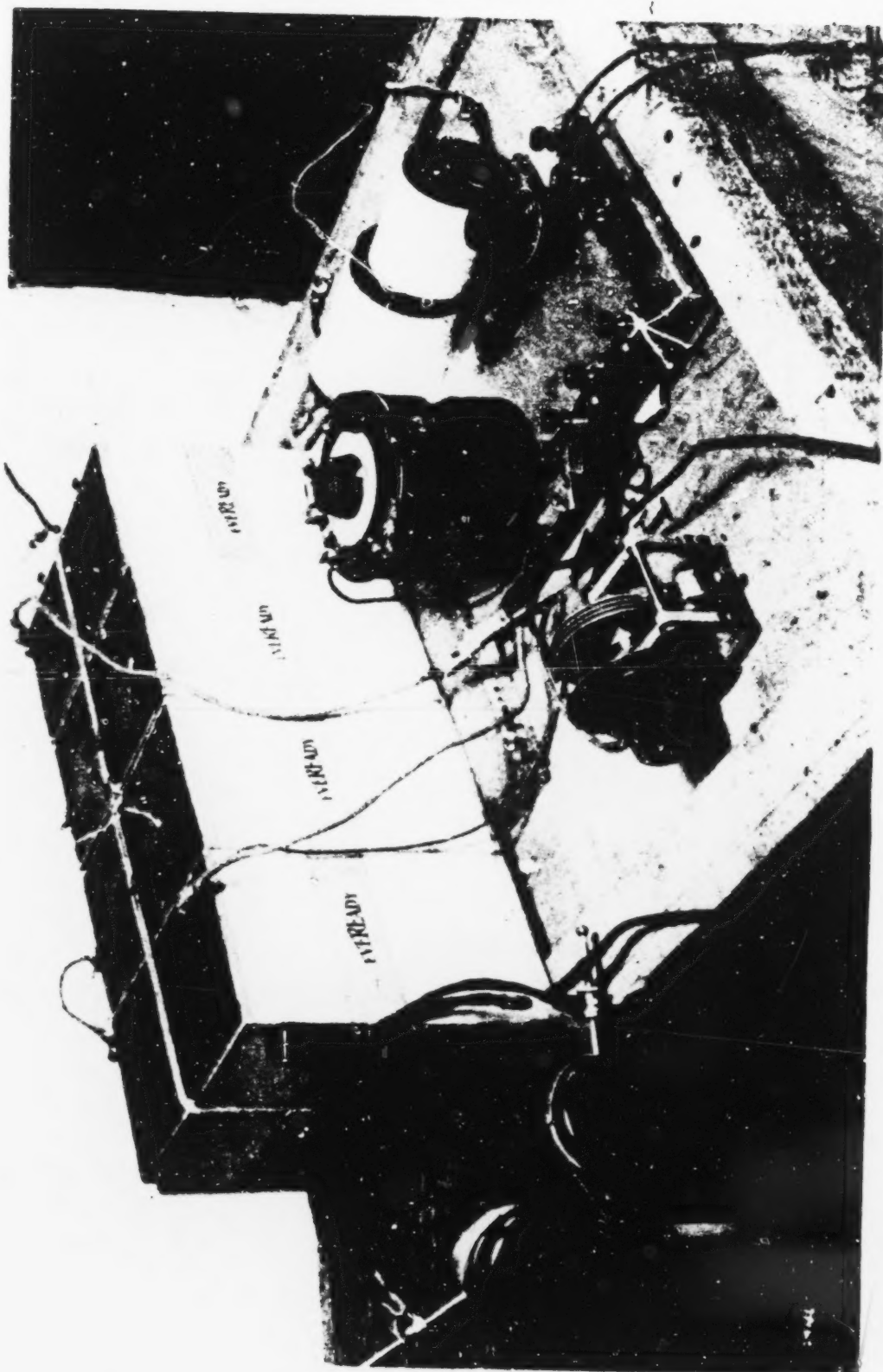


## Claimant's Exhibit No. 302

*Weagant Sketch No 8.*

3190

Claimant's Exhibit No. 315



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Plaintiff's Exhibit 317

3191



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Mauborgne's Sketch  
on Cross Examination

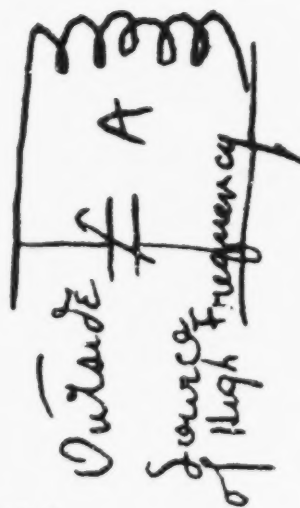
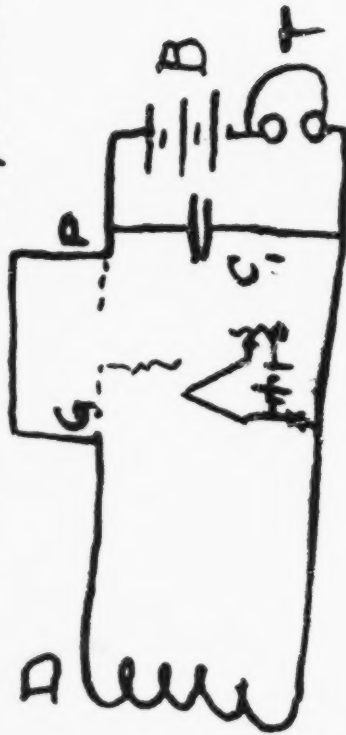
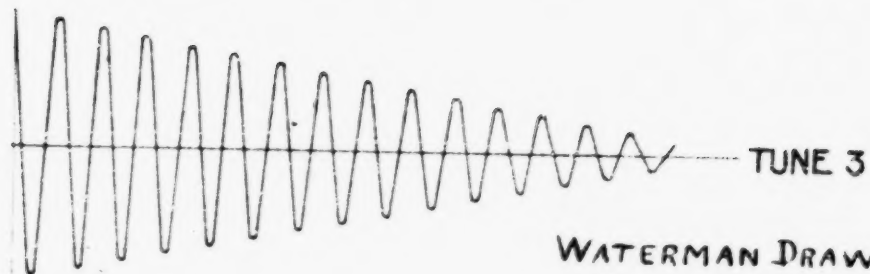
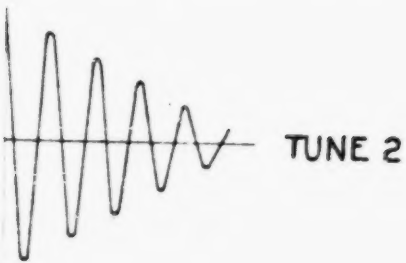
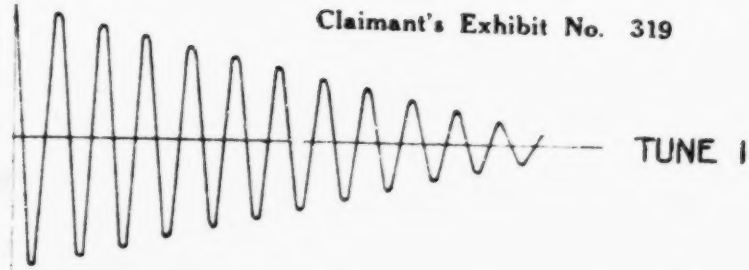


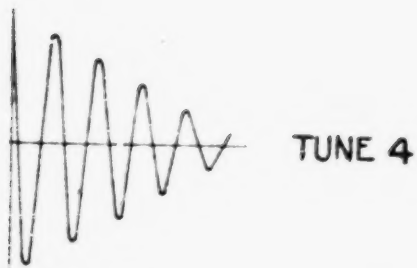
Fig 1

Claimant's Exhibit No. 319



WATERMAN DRAWING NO. 4.  
OSCILLATIONS IN  
PRIMARY CIRCUIT WHEN  
NOT COUPLED TO  
ANTENNA

MARCONI U.S. PAT. 753772



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*unreliable*

*Gilly*

Claimant's Exhibit No. 322  
WATERMAN DRAWING N<sup>o</sup> 5.

FIG. 1.

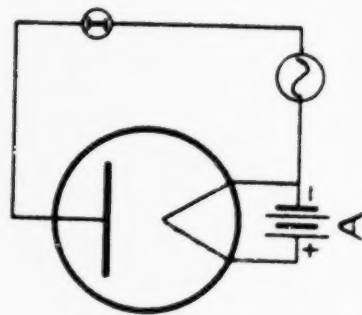


FIG. 2.

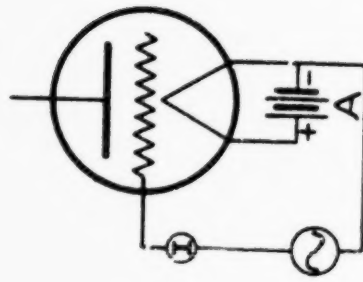
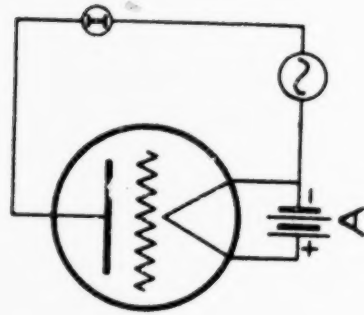


FIG. 3.



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Claimant's Exhibit No. 323  
WATERMAN DRAWING N<sup>o</sup> 6.

FIG. 1.

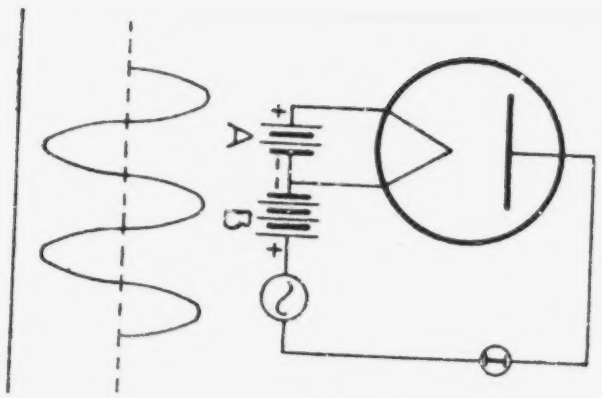


FIG. 2.

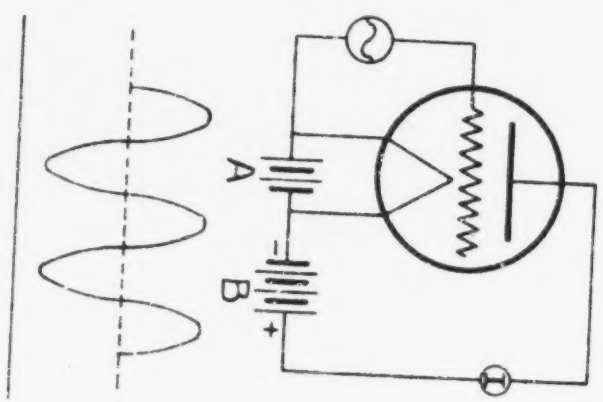
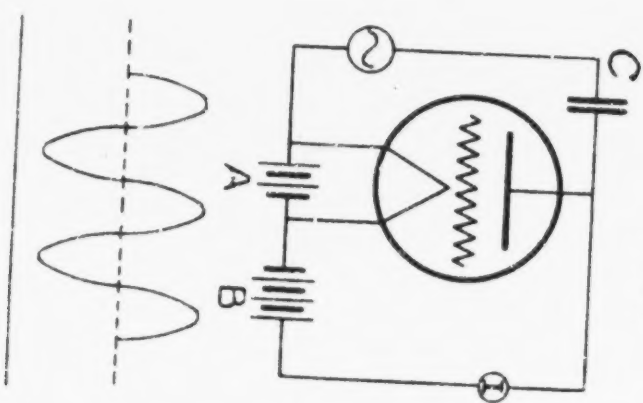


FIG. 3.



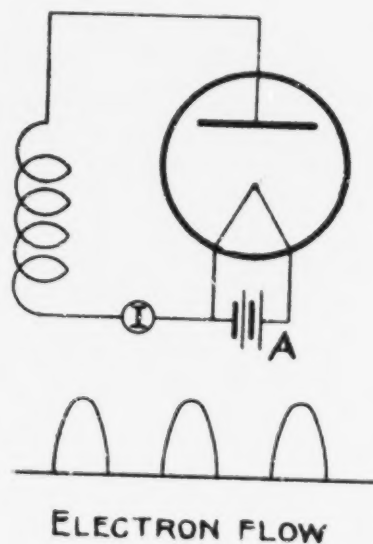
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Claimant's Exhibit No. 324

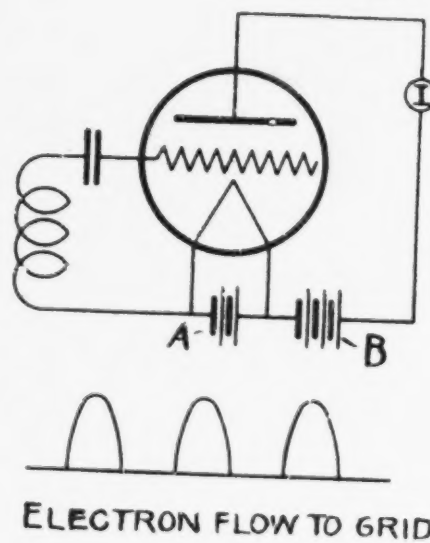
## WATERMAN DRAWING N° 7.

FIG. 1.



CURRENT IN TELEPHONES

FIG. 2.



CURRENT IN TELEPHONES

## COMPARISON:

- 2-ELECTRODE TUBE WITHOUT BIAS BATTERY.  
 3-ELECTRODE TUBE "GRID RECTIFICATION".

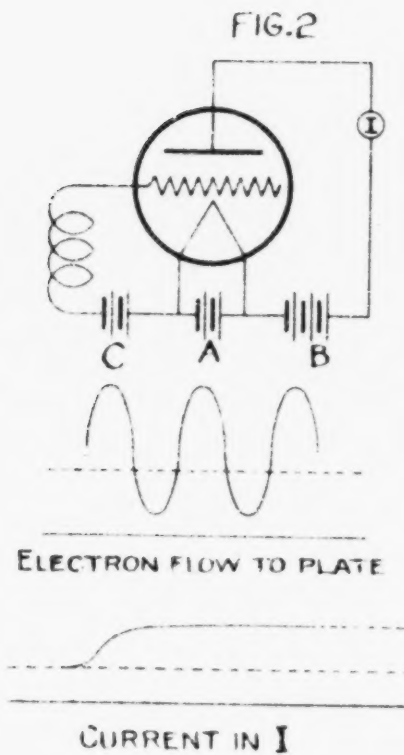
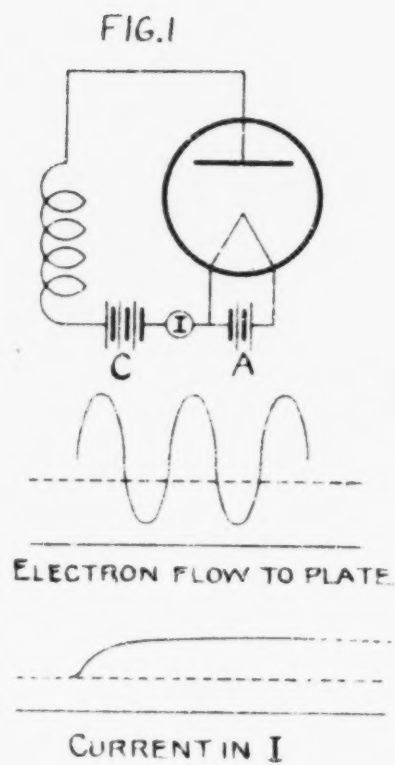
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G. L. G.

Cleitman's Exhibit No. 325

## WATERMAN DRAWING N° 8.



COMPARISON:

2-ELECTRODE TUBE WITH BIAS BATTERY.  
 3-ELECTRODE TUBE (WITH BIAS BATTERY) "PLATE RECTIFICATION."

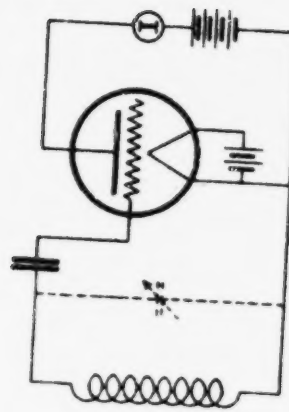
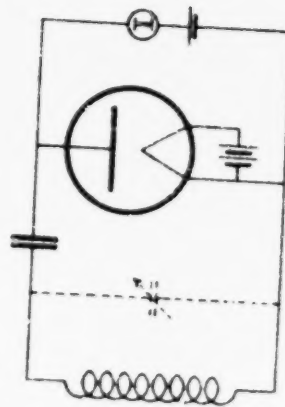
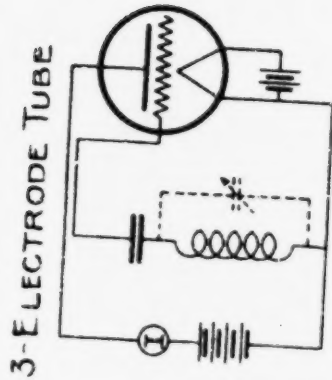
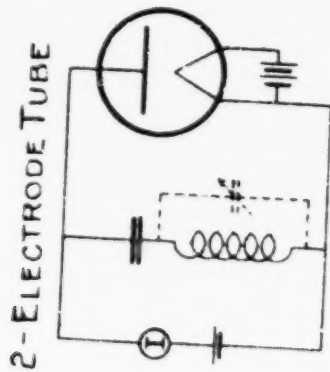
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WATERMAN

WATERMAN

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Claimant's Exhibit No. 326  
**WATERMAN DRAWING N<sup>o</sup> 9.**



COMPARISON OF 2 AND 3 ELECTRODE TUBES IN PN CIRCUIT

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*Ally*

## PLAINTIFF'S EXHIBIT 327 (1)

No. 624,637.

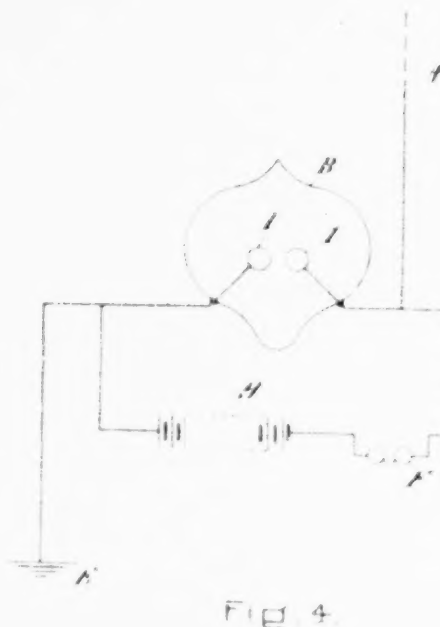
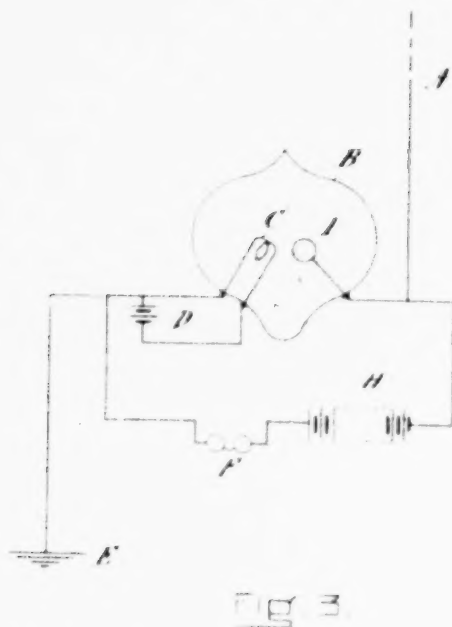
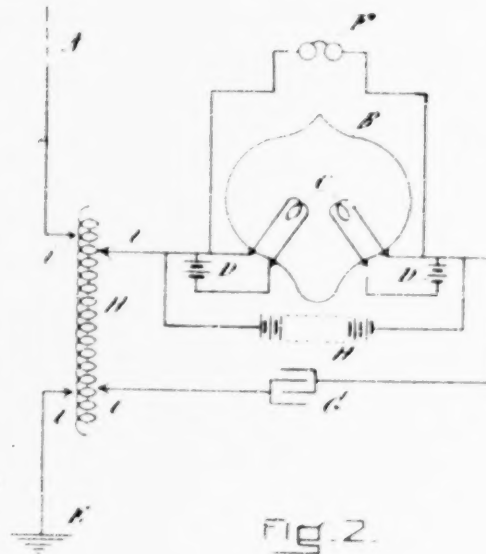
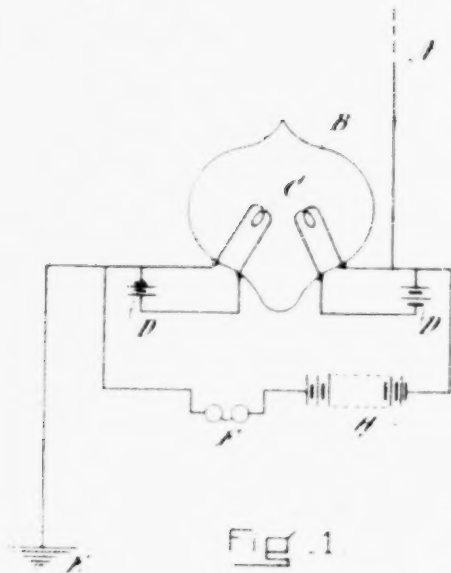
PATENTED JUNE 26, 1906.

L. DE FOREST.

OSCILLATION RESPONSIVE DEVICE.

APPLICATION FILED JAN 18, 1906.

2 SHEETS—SHEET 1



WITNESSES:

Edw. Buckler  
Adolph C. Kaiser

INVENTOR:

Lee de Forest  
by Geo. Woodworth  
Atty.

3200

No. 824,637.

PATENTED JUNE 26, 1906.

L. DE FOREST.  
OSCILLATION RESPONSIVE DEVICE.

APPLICATION FILED JAN 18, 1906

2 SHEETS-SHEET 2

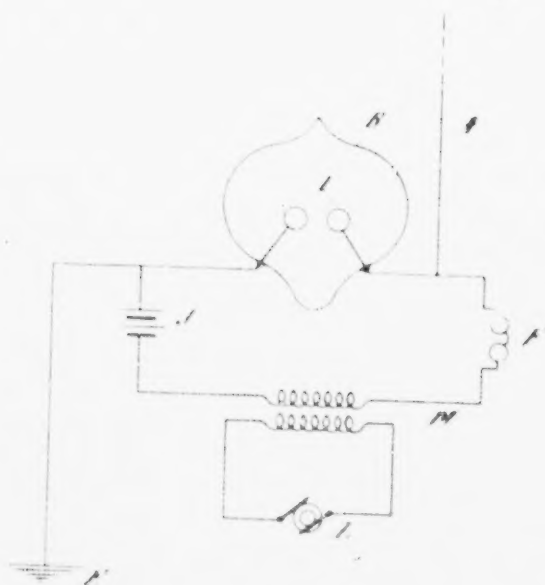


FIG. 5.

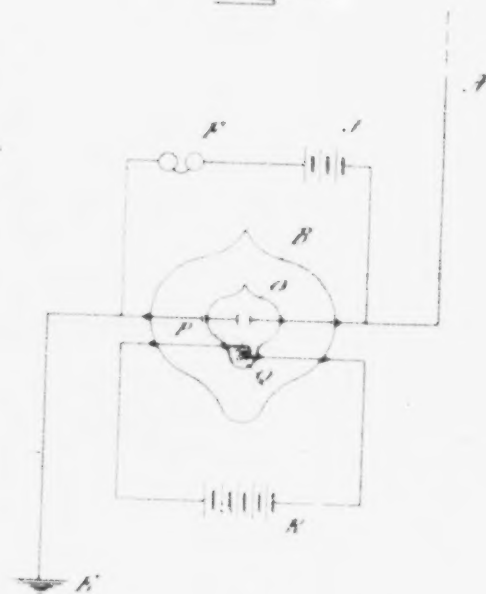


FIG. 6.

WITNESSES:

*John Buckler*  
*Adolph C. Kaiser*

INVENTOR:

*Lee de Forest*  
by *Geo. Woodworth*  
*Atty.*

# UNITED STATES PATENT OFFICE.

3201

LEE DE FOREST, OF NEW YORK, N. Y.

## OSCILLATION-RESPONSIVE DEVICE.

No. 824,637.

Specification of Letters Patent.

Patented June 26, 1906.

Application filed January 18, 1906. Serial No. 296,615.

*To all whom it may concern:*

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful Improvement in Oscillation-Responsive Devices, of which the following is a specification.

My invention relates to devices for detecting feeble electrical currents or oscillations in general, and especially such currents or oscillations which are developed in wireless-telegraph receiving systems.

The object of my invention is to provide an oscillation detector or responder of great simplicity and sensitiveness and one which, inasmuch as it does not depend for its operation upon any variation of resistance of an imperfect electrical contact or any variation of the apparent resistance or counter electromotive force of a polarization-cell, requires no adjustment when employed for receiving wireless-telegraph signals.

With these objects in view my invention comprises a receptacle inclosing a sensitive gaseous conducting medium, the conductivity of which does not necessarily depend upon the heat of combustion, although such conductivity may be increased by heating said gaseous medium, and which in some cases requires practically no heating at all, a wave-intercepting means associated with said gaseous conducting medium, whereby the feeble electrical currents or oscillations resulting from the energy absorbed from electromagnetic signal waves may be impressed upon said gaseous conducting medium to alter its conductivity, and a signal-indicating device operatively connected with said gaseous conducting medium, whereby alterations in the conductivity of the latter may be made manifest.

My invention may best be understood by having reference to the drawings which accompany and form a part of this specification and which illustrate diagrammatically several simple and effective means whereby my invention may be practiced.

In the drawings, Figures 1, 2, 3, 4, 5, and 6 represent wireless-telegraph receiving systems provided with various forms of the oscillation responsive device which forms the subject-matter of the present invention.

In each figure, A represents a receiving antenna connected to earth at E and associated with the receptacle B. In Figs. 1, 3, 4, 5,

and 6 the sensitive gaseous conducting medium inclosed in said receptacle is shown interposed between the antennae and their earth connections, while in Fig. 2 said medium is shown interposed between the terminals of the tuned receiving-circuit  $iCGiH$ , which is inductively associated, by means of the autotransformer H, with the antenna A. By means of the four adjustable contacts  $i$  said tuned receiving-circuit and antenna may each be attuned to the frequency of the waves to be received. My invention, however, is not limited to any particular wireless-telegraph system, nor is it limited to wireless telegraphy, for it may be employed as a detector of feeble electrical impulses however produced.

I have discovered that the gaseous medium intervening between two separated electrodes if put into a condition of molecular activity will become highly sensitive to electrical oscillations, so that the passage across such medium of said oscillations will alter the conductivity thereof, and thereby create current variations in a circuit including said electrodes. The means which may be employed for putting said gaseous medium into a condition of molecular activity may consist of means whereby the medium is heated either by radiation, conduction, or by the actual combustion of gases. An electric current from any suitable source may be employed to heat two highly-resistant electrodes, and thereby to heat the gas intervening between said electrodes without having recourse to the heat of combustion. Said gas may be air, or the electrodes may be inclosed and surrounded by any suitable gas. The heating of the gas may also be affected by radiation from said electrodes. In fact, in the invention disclosed in the present application any suitable means for producing a heated gas with properly dissociated and conducting ions may be employed.

In all the embodiments of the present invention the electrodes are inclosed and are surrounded by suitable gas, and they may be inclosed in a receptacle which may be partially exhausted. Said gas may be rendered sensitive to electrical oscillations by slightly heating the same, preferably by electrical means, or by any other suitable means; but in those embodiments of my invention shown in Figs. 4, 5, and 6 practically no heating at all is required, while if in place of the potassium or other salt hereinafter described as

suitable for use in Fig. 6 some radio-active substance, such as radium bromid, be employed absolutely no heating is necessary.

In Fig. 1 two filaments C, which may be ordinary incandescent-lamp carbon filaments, are sealed into the receptacle B, and each is connected to a separate battery D. The local-circuit battery H and telephone F connect said filaments C. One filament is connected with the antenna A and the other is connected to earth E, although the said filaments may be associated with the antenna in any manner in which existing wireless-telegraph receivers are associated with their receiving antennæ. In lieu of connecting the telephone F in series with the local-circuit battery H said telephone may be connected in shunt to the circuit including the filaments C, which form the electrodes of the oscillation responsive device, and local battery H, as shown in Fig. 2, and such arrangement of telephone-receiver may be employed, if desired, in those embodiments of the present invention which are shown in Figs. 3 to 6, inclusive.

The potential to be impressed upon the electrodes C by the battery H depends upon the nature of the gas intervening between said electrodes and upon the degree of exhaustion maintained within the receptacle B. I have found that from twenty-five to one hundred and ten volts is sufficient, and by employing a higher degree of exhaustion a much smaller voltage may be used. The conductivity of the gas, which may be air or a gas containing compounds of the halogens or halogen salts or which may be mercury vapor, is increased by the heat resulting from the passage of the current from the batteries D through the filaments C, and a leak-current of relatively small value continually flows in the circuit containing the battery H and the electrodes C across the gap intervening between said electrodes. The passage of electrical oscillations across said gap alters the conductivity of the gas in said gap, probably by changing the speed of the ions in said gas, and thereby current variations are produced in the circuit containing the battery H, the electrodes C, and the telephone F, causing said telephone to respond. When the telephone is in series with the battery H and electrodes C, the passage of oscillations across the gap between the electrodes causes an increase of current through the telephone, and when the telephone is in shunt to said electrodes, as shown in Fig. 2, the passage of oscillations across the gap causes a diminution of current through the telephone.

It is not necessary to employ two heated electrodes in carrying out my invention, for, as shown in Fig. 3, one electrode may be replaced by a conductor I, herein shown as a disk, of platinum or other suitable material.

In this case the conductivity of the gaseous medium between the two electrodes I and C is sufficiently increased to render the same sensitive to the electrical oscillations by the radiation of heat from the electrode C.

In that embodiment of my invention shown in Fig. 4 I dispense with both heated electrodes C and substitute therefor two electrodes I, of platinum or other material, and connect the same in circuit with the battery H and telephone F. In Fig. 4 the telephone F may be connected in shunt to the battery-circuit in the manner shown in Fig. 2 of the present case.

In Fig. 5, L represents a source of alternating electromotive force of a frequency so high that a high-pitch note is constantly heard in the telephone F or else so high as to exceed the limit of response of the telephone-diaphragm. The advantage in using the source of alternating electromotive force is that the voltage may be stepped up by a transformer M to any desired amount—for example, from 1'ly to one thousand volts—and impressed upon the electrodes I. In lieu of an alternating-current generator such as shown in Fig. 5 any source of vibratory electromotive force may be employed. The telephone F may be included in series with the circuit containing the secondary of the transformer M and electrodes I, or it may be connected in shunt to said circuit, as above stated in connection with Fig. 2, and the effect of the passage of high-frequency oscillations across the gap between the electrodes I may be increased in the telephone by including a battery J in series with the telephone. In such case the conductivity of the gas in said gap effected by the high-potential alternating current will allow the relatively low potential direct current from the battery J to flow in the circuit containing the telephone and the electrodes, and the passage of electrical oscillations across the gap between the electrodes will produce sudden changes in the conductivity of said gas, and therefore in the amplitude of the current flowing in the telephone-circuit.

A convenient way of producing a gaseous medium containing compounds of suitable salts is shown in Fig. 6, in which a globule of a solution of some such salt is placed in the bottom of a vessel O, as shown at Q, and a heating-coil P is associated with said globule in such a way that the current from the battery K will heat said coil and create a heated gas of said salt in the globe O. I prefer to employ potassium hydrate as the salt to be heated, and better effects may be obtained by inclosing the globe O inside the evacuated globe B to prevent the radiation of heat from the inner globe. The heated gas from the potassium or other salt fills the globe O, which may be exhausted to any desired degree, and completes the circuit of the battery J

and telephone F, which is connected to two electrodes, of platinum or other suitable material, in the globe O. The passage of electrical oscillations across the gap between said electrodes will alter the conductivity of the  
5 the aforesaid heated gas, and thereby create current variations in the circuit of the telephone F.

All the foregoing apparatus comprises  
10 means for sensitizing the interelectrode medium, as suitable salts impregnating the said medium, as before noted, or means for producing and maintaining the medium in a state of molecular activity, as by heating, or both  
15 means for sensitizing may be concurrently employed.

I do not wish to be limited to the particular embodiments of my invention which I have herein disclosed, inasmuch as many  
20 modifications may be made therein by those skilled in the art without departing from the spirit of my invention.

I claim—

1. An oscillation-responsive device comprising a receptacle inclosing a sensitive gaseous conducting medium containing a halogen  
25 salt.

2. An oscillation-responsive device comprising a receptacle inclosing a sensitive gaseous conducting medium containing a halogen  
30 salt and means for heating said medium.

3. An oscillation-responsive device comprising a receptacle inclosing a sensitive gaseous conducting medium containing a potassium  
35 salt.

4. An oscillation-responsive device comprising a receptacle inclosing a sensitive gaseous conducting medium containing a potassium  
40 salt and means for heating said medium.

5. An oscillation-responsive device comprising a receptacle inclosing a sensitive gaseous conducting medium containing a halogen  
45 salt and means for putting said medium in a condition of molecular activity.

6. An oscillation-responsive device comprising a receptacle inclosing a sensitive gaseous conducting medium containing a potassium  
50 salt and means for putting said medium in a condition of molecular activity.

7. An oscillation-responsive device comprising a partially-exhausted receptacle, two separated electrodes sealed in said receptacle  
and each forming part of a separate electric

circuit, a separate source of electric current for each said circuit, and means whereby  
55 electrical oscillations may be impressed upon the gaseous medium intervening between said electrodes.

8. An oscillation-responsive device comprising a partially-exhausted receptacle containing two separated electrodes, a source of  
60 electromotive force associated with said electrodes, and means whereby a relatively small electric current is caused to flow normally in the circuit including said source of electro-  
65 motive force, said electrodes and the gaseous medium intervening between the latter.

9. An oscillation-responsive device comprising a partially-exhausted receptacle containing two separated electrodes, a source of  
70 electromotive force associated with said electrodes, and electrical means for heating said electrodes whereby a relatively small electric current is caused to flow normally in the circuit including said source of electromotive  
75 force, said electrodes and the gaseous medium intervening between the latter.

10. An oscillation-responsive device comprising a receptacle, two separated electrodes inclosed within said receptacle and each  
80 forming part of a separate electric circuit, a source of electric current associated with each said circuit, and means whereby electrical oscillations may be impressed upon the gaseous medium intervening between said electrodes.  
85

11. An oscillation-responsive device comprising a receptacle inclosing a gaseous medium containing a substance the vapor of which is conducting, and electrical means for  
90 heating said medium.

12. An oscillation-responsive device comprising a receptacle inclosing a gaseous medium containing a halogen salt, two separated  
95 electrodes inclosed within said receptacle, and a source of electric current so associated with said electrodes as to render said gaseous medium sensitive to electrical oscillations.

In testimony whereof I have hereunto subscribed my name this 13th day of January, 1906.

LEE DE F. REST.

Witnesses:

LESTER TESTUT,

PHILIP FAIRSWORTH.

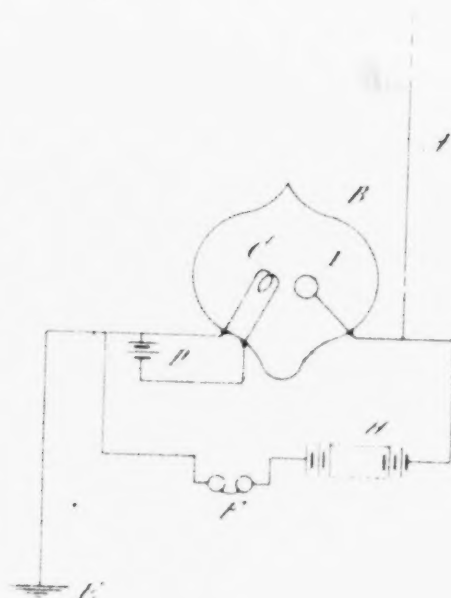
## PLAINTIFF'S EXHIBIT 327 (2)

No. 836,070.

PATENTED NOV. 13, 1906

L. DE FOREST.  
OSCILLATION RESPONSIVE DEVICE.

APPLICATION FILED MAY 12, 1905



WITNESSES:

*John Buckler**Frank A. Parker*

INVENTOR

*L. de Forest*  
*by Geo. H. Woodward*  
*Atty.*

# UNITED STATES PATENT OFFICE.

LEE DE FOREST, OF NEW YORK, N. Y.

## OSCILLATION-RESPONSIVE DEVICE.

No. 836,070.

Specification of Letters Patent.

Patented Nov. 13, 1906.

Original application filed January 18, 1906. Serial No. 396,815. Divided and this application filed May 19, 1906.  
Serial No. 317,721.

*To all whom it may concern:*

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful Improvement in Oscillating Responsive Devices, of which the following is a specification.

My invention relates to devices for detecting feeble electrical currents or oscillations, in general, and especially such currents or oscillations which are developed in wireless-telegraph-receiving systems.

The object of my invention is to provide an oscillation detector or responder of great simplicity and sensitiveness and one which, inasmuch as it does not depend for its operation upon any variation of resistance of an imperfect electrical contact or any variation of the apparent resistance or counter-electromotive force of a polarization-cell, requires no adjustment when employed for receiving wireless-telegraph signals.

With these objects in view, my invention comprises a receptacle inclosing a sensitive, gaseous conducting medium; a wave-intercepting means associated with said gaseous conducting medium whereby the feeble electrical currents or oscillations resulting from the energy absorbed from electromagnetic signal-waves may be impressed upon said gaseous conducting medium to alter its conductivity; and a signal-indicating device operatively connected with said gaseous conducting medium whereby alterations in the conductivity of the latter may be made manifest.

My invention may best be understood by having reference to the drawing which accompanies and forms a part of this specification and which illustrates diagrammatically one embodiment of my invention.

In the drawing, the figure represents a wireless-telegraph-receiving system provided with one form of the oscillation responsive device which constitutes the subject-matter of the present invention.

In the figure, A represents a receiving-antenna connected to earth at E and associated with the receptacle B. Two electrodes C and I are inclosed within said receptacle, which may be partially exhausted, and, as shown, they are sealed in said receptacle. The elec-

trode C may be an ordinary incandescent-lamp-carbon filament, which is connected with a battery or other source of electrical energy D. The electrode I may be any suitable conductor and is herein shown as a disk of platinum or other material. The gaseous medium inclosed between the electrodes C and I is rendered sensitive to electrical oscillations by the radiation of heat from the electrode C, said electrode being heated by the source of energy D. The local circuit containing the battery H or other source of electrical energy and the telephone F or other signal-indicating device is electrically connected with the electrodes C and I, and as shown is connected in series therewith. The antenna A may be associated with either electrode and in such case the other electrode may be connected to earth. It will be understood, however, that the particular mode of associating the oscillation responsive device with the antenna forms no part of my invention and that any suitable system of circuits may be employed with said oscillation responsive device.

The potential to be impressed upon the electrodes C and I by the battery H depends upon the nature of the gas intervening between said electrodes and upon the degree of exhaustion maintained within the receptacle B. I have found that from twenty-five to one hundred and ten volts is sufficient and by employing a higher degree of exhaustion a much smaller voltage may be used. The conductivity of the gas, which may be air, or a gas containing compounds of the halogens or halogen salts or which may be mercury vapor, is increased sufficiently to render said gas sensitive to the passage of electrical oscillation across the gap by the radiation of heat from the electrode C. The passage of electrical oscillation across said gap alters the conductivity of the gas in said gap, probably by changing the speed of the ions in said gas, and thereby current variations are produced in the circuit containing the battery H, the electrodes C and I, and the telephone F, causing said telephone to respond. When the telephone is in series with the battery H and the electrodes C and I, the passage of oscillations across the gap between said electrodes causes an increase of current through the telephone and if the telephone is connect-

ed in shunt with said electrodes, the passage of oscillations across the gap decreases the current through the telephone.

I do not wish to be limited to the particular embodiment of my invention which I have disclosed herein inasmuch as many modifications may be made therein by those skilled in the art without departing from the spirit of my invention.

This application is a division of my application, Serial No. 296,615, filed January 18, 1906.

I claim—

1. An oscillation-responsive device comprising a partially-exhausted receptacle, two separated electrodes sealed in said receptacle, means for heating one only of said electrodes, means whereby electrical oscillations may be impressed upon the gaseous medium intervening between said electrodes, and a local circuit including a source of electrical energy and a signal-indicating device electrically connected with said electrodes.

2. An oscillation-responsive device comprising a partially-exhausted receptacle, two separated electrodes sealed in said receptacle, means for heating one only of said electrodes, means whereby electrical oscillations may be impressed upon the gaseous medium intervening between said electrodes, and a local circuit including a source of electrical energy and a signal-indicating device connected in series with said electrodes.

3. An oscillation-responsive device comprising a partially-exhausted receptacle, two separated electrodes sealed in said receptacle, a source of electric current so associated with one only of said electrodes as to render the gaseous medium intervening between said electrodes sensitive to electrical oscillations, and a local circuit including a source of electrical energy and a signal-indicating device electrically connected with said electrodes.

4. An oscillation-responsive device comprising a partially-exhausted receptacle, separated electrodes sealed in said receptacle, means for heating one only of said elec-

trodes, and a local circuit including a source of electrical energy and a signal-indicating device electrically connected with said electrodes.

5. An oscillation-responsive device comprising a receptacle, two separated electrodes inclosed within said receptacle, means for heating one only of said electrodes, means whereby electrical oscillations may be impressed upon the gaseous medium intervening between said electrodes, and a local circuit including a source of electrical energy and a signal-indicating device electrically connected with said electrodes.

6. An oscillation-responsive device comprising a receptacle, two separated electrodes inclosed within said receptacle, means for heating one only of said electrodes, means whereby electrical oscillations may be impressed upon the gaseous medium intervening between said electrodes, and a local circuit including a source of electrical energy and a signal-indicating device connected in series with said electrodes.

7. An oscillation-responsive device comprising a receptacle, two separated electrodes inclosed within said receptacle, a source of electric current so associated with one only of said electrodes as to render the gaseous medium intervening between said electrodes sensitive to electrical oscillations, and a local circuit including a source of electrical energy and a signal-indicating device electrically connected with said electrodes.

8. An oscillation-responsive device comprising a receptacle, two separated electrodes inclosed within said receptacle, means for heating one only of said electrodes, and a local circuit including a source of electrical energy and a signal-indicating device electrically connected with said electrodes.

In testimony whereof I have hereunto subscribed my name this 10th day of May, 1906.

LEE DE FOREST

Witnesses:

PHILIP FARNSWORTH,  
GEO. L. LEWIS

No. 867,876

PATENTED OCT. 8, 1907.

L. DE FOREST.  
OSCILLATION RESPONSIVE DEVICE.  
APPLICATION FILED APR. 4, 1906



WITNESSES:

Frank G. Parker  
John B. Parker

INVENTOR:

L. de Forest  
By Geo. H. Woodworth  
Attorney.

# UNITED STATES PATENT OFFICE.

THE DE FOREST OF NEW YORK, N. Y., ASSIGNOR TO GEORGE K. WOODWORTH OF BOSTON, MASSACHUSETTS.

## OSCILLATION-RESPONSIVE DEVICE.

No. 867,876

Specification of Letters Patent.

Patented Oct. 8, 1907.

Original application filed February 2, 1906, Serial No. 243,913. Divided and this application filed April 4, 1906.  
Serial No. 399,762.

*Full description of my invention.*

Be it known that I, THE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful Improvement in Oscillation-Responsive Devices, of which the following is a specification.

My invention relates to an improvement in the sensitive member used in systems of wireless telegraphy to detect electrical waves or oscillations and comprises the novel features hereinafter shown and described and particularly pointed out in the claims.

In the accompanying drawing I have shown, and in the description thereof will point out, one form of construction which may be employed in carrying out my invention.

The figure represents a receiving set for a wireless telegraph system, having a sensitive member embodying the principles of my invention.

In the figure, A is an antenna or receiving conductor or wave intercepting means. B, the earth connection. C, the electrodes of the oscillation responsive device, shown in the present case as included in series with the antenna and earth connection. G, a source of current, such as a dynamo, and T, the receiving or indicating instrument, which is herein shown as a telephone receiver, the same being shown only as typical of any form of indicating apparatus capable of being employed for such purpose.

I have discovered that if two bodies adapted for use as electrodes or conductive members be electrically separated, the separation between them may be neutralized sufficiently to enable them to act as a detector of electrical oscillations, if the intervening or surrounding gaseous medium be put into a condition of molecular and ionic activity, such, for instance, as would be caused by heating it in any manner, as by radiation, conduction or by the combustion of gas in the space which surrounds the electrodes. Such condition of molecular and ionic activity causes what would otherwise be a non-sensitive device to become sensitive to the perception of electrical influences. I am thus enabled to employ as such sensitive member device, which would otherwise be of no value and which comprises electrodes separated by a gaseous medium. This principle is embodied in the apparatus shown in the drawing in which the electrodes C are of sufficiently great resistance to be heated by a current from a dynamo G and by their radiation heat the gas between them. This gas may be air or the electrodes may be inclosed and surrounded by any suitable gas as shown. If being a receptacle including said electrodes.

The influence of the oscillations upon the gaseous medium intervening between the electrodes C, which medium is maintained in a condition of molecular and ionic activity by the electrical means described, seems to vary the insulating quality of the gas so that while the influence of the oscillations lasts, the current of the local circuit is varied, thus affecting the indicating device T therein to produce a signal. This may be due to ionization of the gas intervening between the electrodes, which greatly increases the conductivity of said gas, said ionization being accomplished in the present instance by putting said gas in a condition of intense molecular activity.

This application is a division of my application Serial No. 243,913 filed February 2, 1906.

I claim—

1. An oscillation responsive device comprising a receptacle including a sensitive gaseous conducting medium, means for increasing the electrical conductivity of said gaseous medium, means for impressing electrical oscillations upon said medium, and means operatively connected therewith and responsive to alterations in the conductivity thereof.

2. An oscillation responsive device comprising a receptacle including a sensitive gaseous conducting medium, electrical means for heating said gaseous medium, means for impressing electrical oscillations upon said medium, and means operatively connected therewith and responsive to alterations in the conductivity thereof.

3. An oscillation responsive device, comprising a receptacle including a gas, electrical means for rendering said gas sensitive to electrical oscillations, means for impressing electrical oscillations upon said gas and means operatively connected therewith and responsive to alterations in the conductivity thereof.

4. An oscillation responsive device comprising a receptacle including a gas, electrical means for putting said gas in a condition of molecular and ionic activity, means for impressing electrical oscillations upon said gas and means operatively connected therewith and responsive to alterations in the conductivity thereof.

5. An oscillation responsive device comprising a receptacle including a gaseous medium, means for rendering said gaseous medium sensitive to electrical oscillations and means for impressing electrical oscillations upon said gaseous medium.

6. An oscillation responsive device comprising a receptacle including a gaseous medium, means for putting said medium in a condition of molecular and ionic activity whereby it will become the sensitive element of said oscillation responsive device, and means for impressing electrical oscillations upon said gaseous medium.

7. An oscillation responsive device comprising a receptacle including a gaseous medium, electrical means for heating said medium and means for impressing electrical oscillations upon said gaseous medium.

8. An oscillation responsive device comprising a receptacle including a gaseous medium, electrical means for rendering said medium sensitive to electrical oscillations and means for impressing electrical oscillations upon said gaseous medium.

9. An oscillation responsive device comprising an inclosed partially conducting gaseous medium, means for

No. 867,877

PATENTED OCT. 8, 1907.

L. DE FOREST.  
ART OF DETECTING OSCILLATIONS.  
APPLICATION FILED JUNE 12, 1907.

Fig. 1.

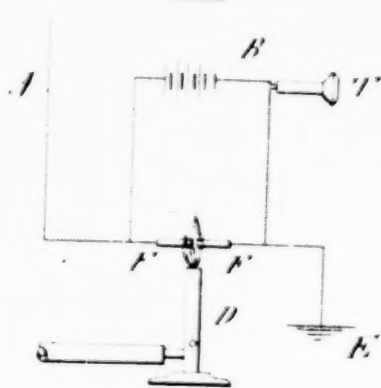


Fig. 2.

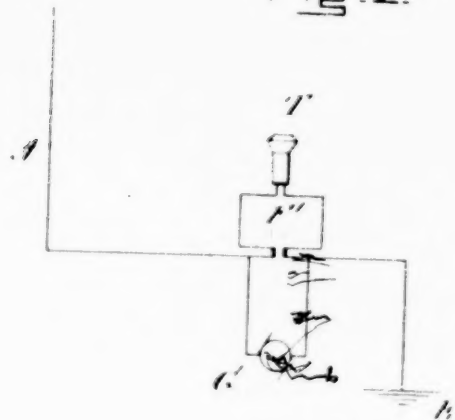


Fig. 3.

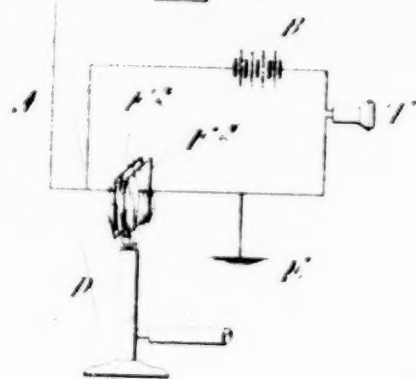


Fig. 4.

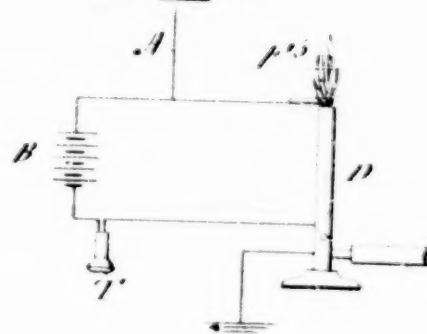
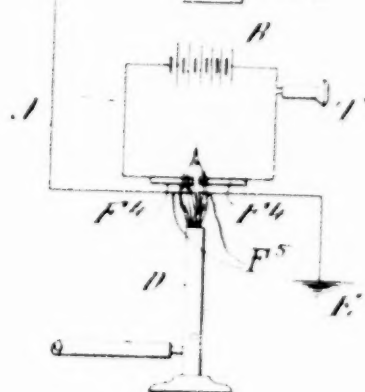


Fig. 5.



WITNESSES:

*John C. ...*  
*...*

INVENTOR:  
*Lee de Forest*  
*by Small Woodworth*  
*att'y.*



ionic activity and having dissociated and conducting ions.

I make no claim herein to the apparatus and circuit arrangements, whatever any method may be carried into effect, inasmuch as such apparatus and circuit arrangements constitute the subject matter of my application Serial No. 233,913, filed Feb. 2, 1905, of which the present application is a division.

I claim:

- 10 1. As an improvement in the art of receiving electro-magnetic signal waves, the method herein described which consists in establishing in a circuit a gaseous medium maintained in a condition of molecular and ionic activity, impressing the electronic oscillations resulting from the waves to be received upon said gaseous medium and thereby altering the electrical condition of the
- 15 2. As an improvement in the art of receiving electro-magnetic signal waves, the method herein described which consists in establishing in a circuit a gas having dissociated conducting ions, altering by the energy of the electronic oscillations resulting from the waves to be received the conductive properties of said gas, and trans-

mitting the resulting current variations into signal indications.

3. As an improvement in the art of receiving electro-magnetic signal waves, the method herein described which consists in causing the electrical oscillations developed by electro-magnetic waves in a wireless telegraph receiving system to vary the electrical conductivity of a gas maintained in a condition of intense molecular and ionic activity and having dissociated and conducting ions, and transmitting the resulting current variations into signal indications.

4. As an improvement in the art of receiving electro-magnetic signal waves, the method herein described which consists in causing the energy of said waves, impressing the resulting electronic oscillations upon a gas maintained in a condition of molecular and ionic activity, thereby altering current variations in the circuit of a source of electromagnetic force associated with said gas and transmitting said current variations into signal indications.

In testimony whereof, I have hereunto signed my name this 11th day of May, 1907.

W. H. D. F. O. L. S.

Witness:

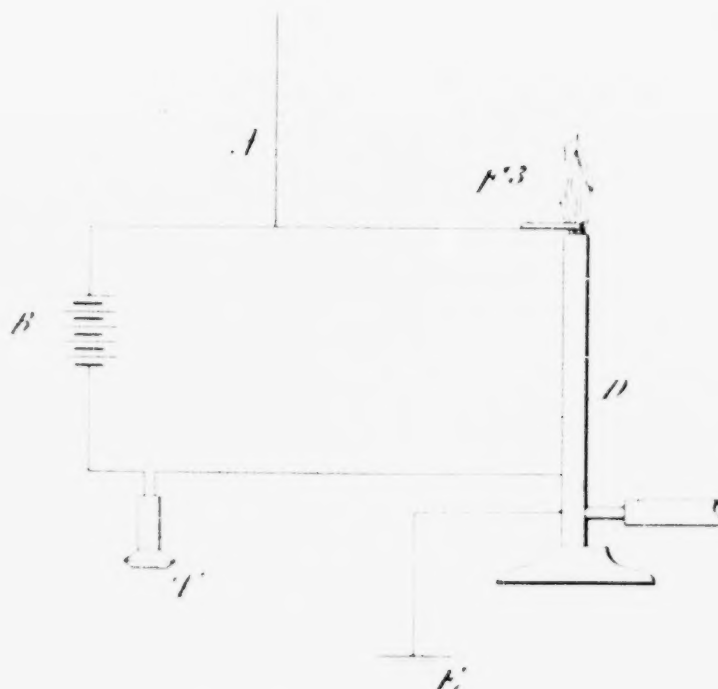
W. H. D. F. O. L. S.  
J. H. H. F. O. L. S.

PLAINTIFF'S EXHIBIT 327 (5)

No. 867,878.

PATENTED OCT. 8, 1907.

L. DE FOREST.  
OSCILLATION DETECTOR.  
APPLICATION FILED JUNE 12, 1907.



WITNESSES:

*Witnesses*  
*Wm. H. Woodworth*

INVENTOR:

*L. de Forest*  
*by Wm. H. Woodworth*  
*Atty.*

## UNITED STATES PATENT OFFICE.

JOSEPH FOREST OF NEW YORK, N. Y., ASSIGNOR TO GEORGE K. WOODWORTH OF BOSTON, MASSACHUSETTS.

## OSCILLATION-DETECTOR.

No. 867,878.

Specification of Letters Patent.

Patented Oct. 8, 1907.

Original application filed February 2, 1905, Serial No. 243,913. Divided and this application filed June 12, 1907.  
Serial No. 378,504.

Be it remembered that I, JOSEPH FOREST, a citizen of the United States, and a resident of New York, in the County of New York and State of New York, have invented a new and useful Improvement in Oscillation-Detectors, of which the following is a specification.

My invention relates to an improvement in the detector member used in systems of wireless telegraphy to detect the electrical waves or oscillations and comprises the following features hereinafter shown and described and particularly pointed out in the claims.

In the accompanying drawing, I have shown, and in the description thereof will point out, a certain form of construction and an arrangement of circuit which may be employed in carrying out my invention, and in the description hereafter I will point out the principle of my invention. It will be understood, however, that I have shown all the known or possible embodiments of my invention are herein illustrated or described and that my particular embodiment herein shown and described may be subjected to a wide range of variation without departing from the principle of my invention. My invention, as here shown, results in a spark telegraph receiving circuit having connected therein one end of an oscillation responsive device which constitutes the detector member of the present invention. It will be understood, however, that such oscillation responsive device and its lead circuit may be connected in any suitable manner with a wireless telegraph receiving circuit.

In the figures, A represents an antenna or receiving circuit, B, or wave-receiving means, C represents the spark coil, D represents a Bunsen burner, E is a receiving or indicating instrument which is connected, as well as a telephone receiver, the same being connected, as represented, at any form of signal indicating device, capable of being employed.

It will be noted that if two electrodes of different members are separated the separation between them may be made sufficiently to enable them to produce a series of electrical oscillations, if they are being passed through which separates and separates the members of the separation of intense molecular activity, as for instance, as shown in the drawing, the two electrodes are separated by a gas medium, the gas being, as shown in the drawing, obviously the gas being passed through in the flame of a Bunsen burner, or as shown at a high temperature, as shown in the drawing, which is a high temperature, as there is formed a red

electrical conductivity, whereby the current from the battery B, if used, will flow more readily from the relatively cold burner D to the more highly heated electrode E, this local circuit comprising the burner D, telephone or other signal indicating device T, electrode E, that portion of the flame intervening between the electrode E and the burner D, and the battery B, if employed. In this case the burner itself forms one of the two electrodes or conductive members above referred to as separated by a gaseous medium maintained in a condition of intense molecular and ionic activity.

Although I have shown a Bunsen burner for the purpose of maintaining the gaseous medium intervening between the electrodes D and E in a condition of intense molecular activity by the combustion of gases intervening between said electrodes, it will be understood that I do not limit myself to this particular heating device, which is not essential, as any means of heating may be employed.

The influence of the electrical oscillations developed in the oscillation circuit A, C, produces current variations in the adjacent local circuit, thus affecting the indicating instrument thereon to produce a signal. This may be due to ionization of the gas intervening between the electrodes, which greatly increases the conductivity of said gas, said ionization being accomplished in the present instance by passing said gas into a condition of intense molecular activity.

This application is a division of my application Serial No. 243,913, filed February 2, 1905, and the drawing accompanying the present application is identical with Fig. 4 of the patent application.

I claim:

1. An oscillation detector, comprising a Bunsen burner, an electrode placed in the flame thereof, and a circuit connecting said burner and electrode, a signal indicating device, and a source of electromotive force connected in series with said circuit, and means whereby the said circuit may be connected to a wireless telegraph receiving circuit.

2. An oscillation detector, comprising a Bunsen burner, an electrode placed in the flame thereof, and a circuit connecting said burner and electrode, a signal indicating device, and a source of electromotive force connected in series with said circuit, and means whereby the said circuit may be connected to a wireless telegraph receiving circuit.

3. An oscillation detector, comprising a Bunsen burner, an electrode placed in the flame thereof, and a circuit connecting said burner and electrode, a signal indicating device, and a source of electromotive force connected in series with said circuit, and means whereby the said circuit may be connected to a wireless telegraph receiving circuit.

the electromotive force included in said local circuit, a signal indicating device operatively connected with said local circuit and means whereby the oscillations to be detected may be impressed upon said gaseous medium.

- 5 1. An oscillation responsive device comprising a gaseous medium maintained in a condition of molecular and ionic activity, two electrodes associated with said gaseous medium, one of said electrodes being maintained at a high temperature and the other at a relatively lower temperature, means whereby the oscillations to be detected may be impressed upon said gaseous medium, and means operatively connected therewith and responsive to alterations in the conductivity thereof.

- 10 2. An oscillation responsive device comprising a gaseous medium maintained in a condition of molecular and ionic activity, two electrodes associated with said gaseous medium, one of said electrodes being maintained at a relatively high temperature, with respect to the other, means whereby the oscillations to be detected may be

impressed upon said gaseous medium, a local circuit containing said electrodes and a signal indicating device operatively associated with said local circuit.

3. A wireless telegraph local receiving circuit having a portion of its length formed of a gaseous medium maintained in a condition of intense molecular and ionic activity and possessing an asymmetric electrical conductivity, a signal indicating device operatively associated with said local circuit and means whereby the oscillations to be detected may be impressed upon said gaseous medium.

In testimony whereof, I have hereunto subscribed my name this 14th day of May 1907.

LEE DE FOREST

Witnesses:

Charles F. Fitzgerald

George Keyes

Correction in Letters Patent No. 867,878.

It is hereby certified that in Letters Patent No. 867,878, granted October 8, 1907, upon the application of Lee de Forest, of New York, N. Y., for an improvement in "Oscillation-Detectors," an error appears in the printed specification requiring correction, as follows: In line 85, page 1, the word "patent" should read *parent*; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 29th day of October, A. D., 1907.

[SEAL.]

E. B. MOORE,

Commissioner of Patents.

PLAINTIFF'S EXHIBIT 327 (6)

3216

No. 841,386

L. DE FOREST.  
WIRELESS TELEGRAPHY.  
APPLICATION FILED AUG. 27, 1906

PATENTED JAN. 15, 1907.

2 SHEETS SHEET 1

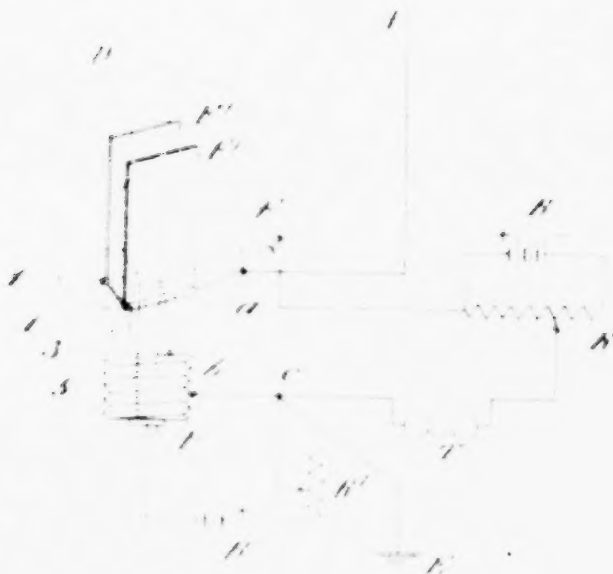


Fig. 1



Fig. 2

WITNESSES:

Frank S. Porter  
Edw. E. E. E.

INVENTOR:

L. de Forest  
by E. H. Woodworth  
Atty.

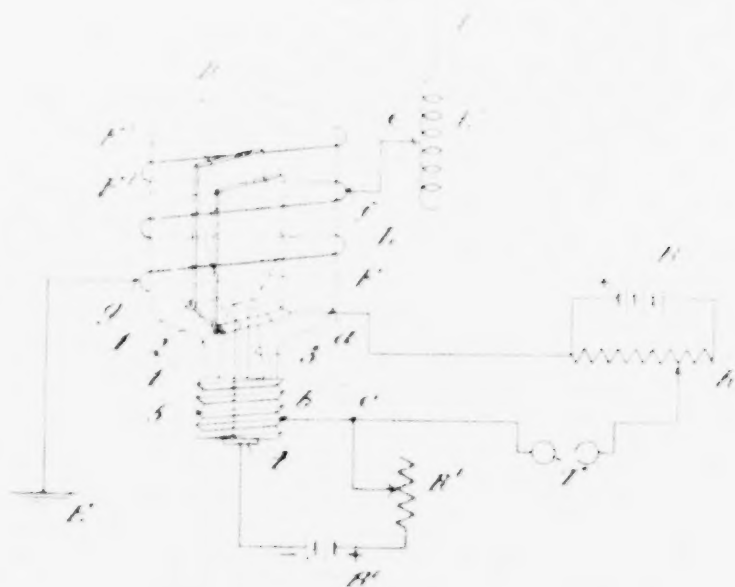


Fig. 4.

WITNESSES:

Frank A. Parker  
John A. Parker

INVENTOR:

Lee de Forest  
by Geo. K. Woodworth  
Atty.

## UNITED STATES PATENT OFFICE.

LEE DE FOREST, OF NEW YORK, N. Y.

## WIRELESS TELEGRAPHY.

No. 841,386.

Specification of Letters Patent.

Patented Jan. 15, 1907.

Application filed August 27, 1906. Serial No. 332,213.

*To all whom it may concern:*

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful Improvement in Wireless Telegraphy, of which the following is a specification.

My invention relates to wireless telegraphy and more particularly to an oscillation-detector which, in addition to performing the usual functions of such detectors, may be used as a tuning device and as a static valve, and which has a variety of other uses.

I have discovered that if the gaseous medium intervening between separated electrodes be put into a condition of molecular activity, as by heating the same or otherwise, said medium becomes highly sensitive to electrical oscillations, as more fully set forth in my application, Serial No. 243,913.

I have shown in my application, Serial No. 300,975, that the sensitiveness of an oscillation-detector comprising electrodes separated by such sensitive gaseous medium may be varied by the action of a magnetic field, so that the response of said detector *per se* is a function of a characteristic, such as the frequency, of the electrical oscillations operating upon the same. Thus, for certain frequencies a magnetic field of given strength will greatly decrease the sensitiveness of the detector and render it practically non-responsive, while for other frequencies the same magnetic field will greatly increase the sensitiveness of the detector. In short, said detector *per se* may be made selectively responsive without having recourse to tuned or resonant circuits, so that the use of such circuits may be dispensed with and the detector itself employed to perform the functions heretofore effected by said circuits.

The subject-matter of the present invention is an oscillation-detector which, like that above referred to, may be made selectively responsive to electrical oscillations having a given frequency or electrical rate of vibration but which does not require a proximate magnetic field for this purpose, and which also may be made selectively responsive to electrical oscillations having a given spark, or wave-train, frequency—that is to say, may be so adjusted that its response to electrical oscillations is a function of the number of groups or trains of waves per second, irrespective of the electrical frequency of such waves.

By virtue of the selective properties of my oscillation-detector as above set forth, I am enabled to employ said detector as a tuning device and also as a static valve or leak; and on account of its indestructibility I am enabled to employ the detector in those systems where large amounts of energy are created in the immediate proximity of said detector, such, for example, as the duplex systems described in my United States Letters Patent No. 772,879, dated October 18, 1904, and in the systems which permit "breaking" between two operators as set forth in my United States Letters Patent Nos. 827,523 and 827,524, dated July 31, 1906.

My invention may best be understood by having reference to the drawings which accompany and form a part of this specification and which diagrammatically illustrate four embodiments thereof which have successfully been employed; but I do not wish to limit myself to the details shown therein inasmuch as many other forms of construction and arrangement of circuits embodying the principles of my invention, as particularly pointed out in the appended claims, will readily occur to those skilled in the art.

In the drawings, Figure 1 represents a simple form of my oscillation-detector conductively connected with a receiving-antenna. Fig. 2 represents a detail of construction used in connection with the detectors shown in Figs. 1, 3 and 4. Fig. 3 represents a modification of the detector shown in Fig. 1 in which the detector is energized by an electric field developed by the oscillations to be detected. Fig. 4 represents a further modification in which the detector is energized by a magnetic field created by the oscillations to be detected.

In the figures, A is a receiving-antenna.

E is an earth connection.

M is a transformer, of which  $I_1$  and  $I_2$  are the primary and secondary windings.

BB' are batteries.

RR' are resistances.

LL' are inductances.

T is a telephone or other signal-indicating device.

D represents an evacuated vessel of glass or other suitable material having two separated electrodes F and F' between which intervenes the gaseous medium which, when sufficiently heated or otherwise made highly conducting, forms the sensitive element of

oscillation detector. While various means may be employed for heating said gaseous medium, I find it convenient to employ electrical means, and therefore I prefer to employ as the electrode F a filament of carbon or metal and to connect the same in series with a battery B and a rheostat R. I have ascertained that a filament of metal especially one of carbon, renders the oscillation detector much more sensitive than one of carbon.

The electrode F may consist of a non-coated metallic body such as shown in the present instance as the wings or plates F' F' so much to the metallic base 2, which may be supported by the upwardly extending portion 3 of the vessel D, although any suitable means may be used to support the electrode F within said vessel.

While I have shown and described the electrode F as consisting of two wings or plates, it will be understood that said electrode may have any other form suitable for the purpose, although I have found that better results are obtained by using two flat plates or wings than by using a flattened cylinder and that a flattened cylinder gives better results than a cylinder of circular section. The reason for this is that the sensitiveness of the device, other things being equal, depends in a measure upon the distance between the electrodes F F' and the minimum separation can be obtained by using flat plates for the electrode F'. As will be obvious, the electrode F' may consist of one flat plate.

The evacuated vessel D may be provided with a screw socket 5 after the manner of ordinary incandescent lamps, and one end of the filament F may be conductively connected thereto while the other end may be insulated therefrom and conductively connected to the contact point 4 in the base of the socket. In such case the terminals of the heating battery B are connected respectively to the socket at 5 and to the contact point 4.

The terminals of the local circuit, which includes the battery B and signal-indicating device, such as the telephone T, are connected respectively to the electrodes F and F' at a and b. Means may be included in or associated with the local circuit for varying the potential developed by the local circuit B between the points a and b. For this purpose the number of cells which make up the battery B may be varied, or the adjustable resistance R, which, with the battery, constitutes a potentiometer, may be used.

The oscillation detector, as above described, may be associated with the receiving system in a variety of ways now well known in the art by connecting the electrode F to one of the terminals of the source of oscillations and the electrode F' to the other term-

inal thereof. In the present instance the antenna A is connected to the electrode F' by a leading-in wire which is connected to the base 2 and which is sealed in the vessel D at 2, and the earth-conductor is connected to the electrode F through the socket 5 and the conductor 4.

It is preferable that the positive pole of the battery B should be connected to the electrode F' and better results are obtained if the negative pole of the battery B be connected to that end of the filament F to which the positive pole of the battery B' is connected, as shown in Figs. 1, 3, and 4 as that end of said filament which is connected to the screw-socket.

By regulating and adjusting the amount of heating current flowing in the circuit of the battery B, the sensitiveness of my detector may be varied, so that the response of the detector *per se* will be a function of the frequency of the electrical oscillations operating upon the same, and said detector itself, as distinguished from the circuit in which it is included, will be selectively responsive to oscillations having a given electrical frequency. For regulating and adjusting the heating current flowing through the filament F, I may employ the rheostat R' or any other means suitable for the purpose.

For tuning the oscillation-detector to oscillations of given electrical frequency, the amplitude of the heating current must be determined empirically, as by adjusting the rheostat R, because a number of factors such, for example, the separation of the electrodes F F' and the difference of potential developed by battery B across the points a b, are involved.

By regulating and adjusting the potential impressed by the battery B across the electrodes F F', the sensitiveness of the detector may be varied so that the response of the detector *per se*, other things being equal, will be a function not only of the electrical frequency or wave length of the oscillations operating upon the detector, but also of the spark frequency which *ceteris paribus* is a measure of the total energy received, and the detector itself, as distinguished from a circuit tuned electrically to electrical or to spark frequency and from a mechanism tuned mechanically or acoustically to spark frequency, will be selectively responsive to oscillations having a given electrical frequency, and also to oscillations having a given spark frequency irrespective of their electrical frequency or wave length. Thus, with a given separation of the electrodes F F' and a given amplitude of heating-current flowing through the filament F, I have been able by merely varying the potential of the battery B to attune the oscillation-detector to the oscillations developed in the receiving system by one of several transmitting systems and to receive the energy there-

of to the exclusion of the energies of the oscillations developed therein by the other of said transmitting systems, even when the several sets of oscillations had the same electrical frequency and wave length, but differed in spark frequency or in average energy conveyed per unit of time. Here also the adjustment of the potential impressed by the battery B upon the electrodes F F' must be determined empirically.

By virtue of the selective properties of my detector, as above set forth, I am enabled to effect by the detector itself a method of double-tuning which affords the greatest security from waves the energy of which is not intended to affect the detector as well as from atmospheric or "static" electricity and other disturbing electrical forces.

As above mentioned, the sensitiveness of my oscillation detector, which in common with others of my invention employing a conducting gaseous medium as the sensitive element I call the "audion," is a function of the separation of the electrodes or of the length of the sensitive conducting gaseous medium; but I find that here again the frequency is a determining factor, so that by varying the separation of the electrodes I can make the response of the audion a function of the frequency. In other words, by suitably varying the length of the interelectrode medium, other adjustments, such as those of the batteries B B', remaining unchanged, I am enabled to make the audion *per se* selectively responsive to oscillations of a given frequency independently of the usual tuned or resonant circuit heretofore employed in wireless telegraphy as a current or oscillation selector.

A convenient means of varying the distance between the electrodes F F' is to hinge the wings which constitute the electrode F' to the base 2 as by the hinges 1 1'. By approaching the magnets 6 6 to the inverted tube, as shown in Fig. 2, the wings, which may be made wholly or partly of iron, will open outwardly away from the filament and thereby increase the path of the conducting ions in the interelectrode medium.

When the audion is to be attuned to oscillations of a given frequency by varying the separation of the electrodes, the adjustment produced by the magnets 6 6 must be empirically determined, just as the adjustments of the batteries B B', above referred to are purely empirical.

It will be understood that each of the three methods above set forth for varying the response of the audion in accordance with the electrical frequency and the spark frequency of the oscillations to be detected may be separately employed and also that any two or all three of said methods may be used conjointly. For example, by appropriately varying the separation of the elec-

trodes F F' and the amplitude of the heating-current from the battery B', the audion may be made selectively responsive to waves of a given electrical frequency, and then by the regulation and adjustment of the potential impressed upon the audion by the battery B, the audion may be made to select a particular one of a number of sets of waves all having the said electrical frequency and wave length, but each set having a spark frequency different from that of any other set.

The oscillation-detectors shown in Figs. 3 and 4 are identical in construction with those above described in connection with Figs. 1 and 2, and differ therefrom merely in the manner in which they are associated with the source of oscillations to be detected.

In Fig. 3, 7 represents a metallic member brought into proximity with the vessel D and shown in the present instance as a cylinder surrounding said vessel. In this case one terminal of the oscillation source which in the present instance is shown as a circuit including the secondary of the transformer M, is conductively connected to the cylinder 7 at the point *d*, while the other terminal may be connected to either one of the electrodes F or F' and in the present instance is shown as connected to the electrode F through the socket 5 and conductor *b c*. In this case the oscillating electric field developed by the electrical oscillations in the secondary winding *I*<sub>2</sub> operates to alter the conducting properties of the sensitive conducting gaseous medium in the vessel D and thereby to vary the current flowing in the local circuit which includes the telephone T, just as in the case of the system shown in Fig. 1 in which the terminals of the oscillation source are connected directly to the interelectrode medium.

The arrangement shown in Fig. 3 affords a fourth method of rendering the audion selectively responsive, for in addition to the three methods above set forth in connection with Figs. 1 and 2 I find that, other things being equal, the response of the audion to oscillations of a given frequency is a function of the area of the surface of the member 7 and of the separation thereof from the elements within the vessel D.

If the form shown in Fig. 3 be employed, the cylinder 7 may be moved with respect to the axis of the vessel D until, *ceteris paribus*, the response of the audion is a maximum for oscillations of a given frequency. It will be understood of course that the separation of the electrodes F, F', and the values of the resistances R, R', of the audion shown in Fig. 3 may all be varied in the manner above explained in connection with Figs. 1 and 2.

When the connections shown in Fig. 3 are used I find that the quality of the sound produced in the telephone T is quite different

from that produced therein when the connections shown in Fig. 1 are used, although the sounds may be, and under the same conditions are, of equal intensity. When the connections shown in Fig. 1 are employed, the sounds produced by the telephone are sharp and crackling, as is the case where various other forms of oscillation-detector are employed, but when the connections shown in Fig. 3 are used, the sounds produced by the telephone, under the same conditions as before, are muffled or drummy. This latter sound is distinctive and is not produced by the use of any other form of oscillation-detector so far as I am aware. The advantage of obtaining the latter sound in the telephone is that it may readily be distinguished from the sounds produced therein by atmospheric electricity, whereas the sharp crackling sounds produced in the telephone by the signal-waves when other types of oscillation detector are used very nearly imitate the sounds produced therein by static disturbances or atmospheric electricity.

In the arrangement shown in Fig. 4 the audion is energized by the oscillating magnetic field developed by the passage of the oscillations to be detected through the coil L, which surrounds the sensitive conducting gaseous medium and which in the present instance is wound around the outside of the tube. This coil preferably is made adjustable, as by the contacts *f* and *g*, and the antenna A may include an inductance *L'* having an adjusting contact *e*. It will be understood that the adjustments of the separation of the electrodes *E*, *E'*, of the amplitude of the heating current and of the value of the potential impressed between the points *a* and *b*, as set forth above in connection with Fig. 1, may also be employed to render the audion shown in Fig. 4 selectively responsive. I have ascertained also that the variation of the magnetic field created by the passage of oscillations through the coil L, varies the response of the audion, other things being the same, and furthermore that this variation also is a function of frequency. In other words, having adjusted the audion to be most responsive to oscillations of given frequency in the manner above described in connection with Fig. 1, there may be found empirically a certain position for the contacts *f* or *g*, at which for oscillations of a said frequency the response of the detector is a maximum.

The syntonizing inductance *L'*, or other electrical tuning device, may be employed in connection with any of the several embodiments of my present invention so as to combine the selectivity of the antenna or tuned receiving-circuit with the selective properties of the oscillation-detector itself, and in such cases I have found the selectivity of a receiving system so constructed to be very high indeed.

It will be understood that in all cases, if desired, the vessel D may include the vapor of a halogen salt or other substance the vapor of which is conducting or a gas whose conductivity is greater than that of air under an attenuated pressure.

I claim

1. An electrical-oscillation-selecting device comprising a vessel, a filament sealed in said vessel, a source of electric current connected in series with said filament, means for varying the amplitude of said current, whereby said device is rendered selective of electrical oscillations having a given electrical frequency, a member of conducting material inclosed within said vessel and a circuit connecting said member with said filament.

2. An electrical-oscillation-selecting device comprising a vessel, a filament sealed in said vessel, a source of electric current connected in series with said filament, a member of conducting material inclosed within said vessel, a circuit connecting said member with said filament, a source of electromotive force associated with said circuit and means for varying said electromotive force, whereby said device is rendered selective of electrical oscillations having a given spark frequency.

3. An electrical-oscillation-selecting device comprising a vessel, a filament sealed in said vessel, a source of electric current connected in series with said filament, means for varying the amplitude of said current, whereby said device is rendered selective of electrical oscillations having a given electrical frequency, a member of conducting material inclosed within said vessel, a circuit connecting said member and said filament, a source of electromotive force associated with said circuit and means for varying said electromotive force, whereby said device is rendered selective of electrical oscillations having a given spark frequency.

4. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium maintained in a condition of molecular activity, two electrodes inclosed within said vessel, and means for varying the separation of said electrodes.

5. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium maintained in a condition of molecular activity, two electrodes inclosed within said vessel, and means outside said vessel for varying the separation of said electrodes.

6. An electrical-oscillation-selecting device comprising a vessel, a filament sealed in said vessel, a source of electric current connected in series with said filament, a member of conducting material inclosed within said vessel, a circuit connecting said filament and said member and means for varying the separation of said filament and said member.

7. An electrical-oscillation-selecting device comprising a vessel, a filament sealed in

said vessel, a source of electric current connected in series with said filament, and means for varying the amplitude of said current, whereby said device is rendered selective of electrical oscillations having a given electrical frequency.

8. An electrical-oscillation-selecting device comprising a vessel, a filament sealed in said vessel, a source of electric current connected in series with said filament, a member of conducting material inclosed within said vessel, a circuit connecting said filament with said member, a source of electromotive force associated with said circuit, means for varying said electromotive force and means for varying the separation of said filament and said member.

9. An electrical-oscillation-selecting device comprising a vessel, a filament sealed in said vessel, a source of electric current connected in series with said filament, means for varying the amplitude of said current, whereby said device is rendered selective of electrical oscillations having a given electrical frequency, a conductor inclosed within said vessel, a circuit connecting said conductor and filament, a source of electromotive force associated with said circuit and means for varying said electromotive force, whereby said device is rendered selective of electrical oscillations having a given spark frequency.

10. An oscillation-detector and means whereby said detector *per se* is rendered selective of electrical oscillations having a given spark frequency.

11. An oscillation-detector, means whereby said detector *per se* is rendered selective of electrical oscillations having a given electrical frequency and means whereby said detector *per se* is rendered selective to electrical oscillations having a given spark frequency.

12. An electrical-oscillation-selecting device comprising a vessel containing a sensitive conducting gaseous medium, two electrodes within said vessel, a local circuit connecting said electrodes, a receiving-circuit having one terminal connected with one of said electrodes, a conducting member outside said vessel and movable with respect thereto, and an electrical connection from the other terminal of said receiving-circuit to said conducting member.

13. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium maintained in a condition of molecular activity, two electrodes inclosed within said vessel, means for impressing an electrical potential upon said electrodes, and means for varying said potential.

14. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium, an electrode within said vessel, means for heating said electrode, means for regulating the temperature thereof, a second

electrode inclosed within said vessel and a circuit connecting said electrodes.

15. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium, an electrode within said vessel, means for heating said electrode, means for regulating the temperature thereof, a second electrode inclosed within said vessel, means for impressing an electrical potential upon said electrodes and means for varying said potential.

16. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium maintained in a condition of molecular activity, two electrodes inclosed within said vessel, a local circuit connecting said electrodes and means for varying the separation of said electrodes.

17. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium, an electrode within said vessel, means for heating said electrode, means for varying the temperature thereof, a second electrode inclosed within said vessel and means for varying the separation of said electrodes.

18. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium, an electrode within said vessel, means for heating said electrode, means for varying the temperature thereof, a second electrode inclosed within said vessel, a circuit connecting said electrodes, an adjustable source of electromotive force associated with said electrodes, and means for varying the separation of said electrodes.

19. An electrical-oscillation detector comprising a vessel inclosing a gaseous medium, means for maintaining said gaseous medium in a condition of molecular activity, a member in proximity to said vessel, and an oscillation-circuit electrically connected to said member and to said gaseous medium.

20. An electrical-oscillation-selecting device comprising a vessel inclosing a gaseous medium, means for heating said medium, and means for varying the temperature thereof, whereby said device is rendered selective of electrical oscillations having a given electrical frequency.

21. An oscillation-detector comprising two conductively-connected flat plates of conducting material inclosed within an evacuated vessel, an electrode sealed within said vessel and located between said plates, and means for heating said electrode.

22. An oscillation-detector comprising two conductively-connected flat plates of conducting material inclosed within an evacuated vessel, a metallic filament sealed within said vessel and located between said plates, and means for heating said filament.

23. An oscillation-detector comprising two conductively-connected flat plates of con-

ducting material inclosed within an evacuated vessel, a filament of tantalum sealed within said vessel and located between said plates, and means for heating said filament.

24. An oscillation detector comprising two flat plates of conducting material inclosed within an evacuated vessel, an electrode sealed within said vessel and located between said plates, and means for heating said electrode.

25. An oscillation detector comprising two

flat plates of conducting material inclosed within an evacuated vessel, a filament sealed within said vessel and located between said plates, and means for heating said filament.

In testimony whereof I have hereunto subscribed my name this 24th day of August, 1906.

LEE DE FOREST

Witnesses

GEO. E. TERRY,

GEO. K. WOODWORTH.

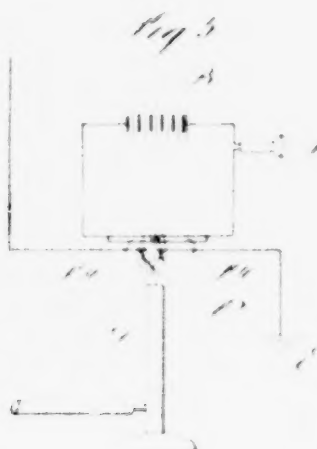
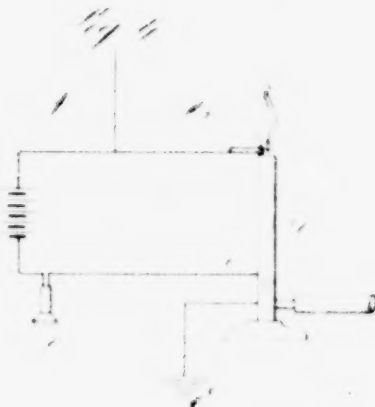
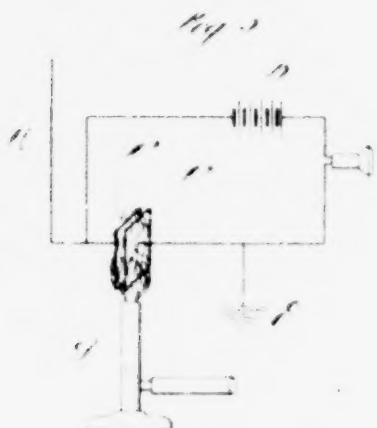
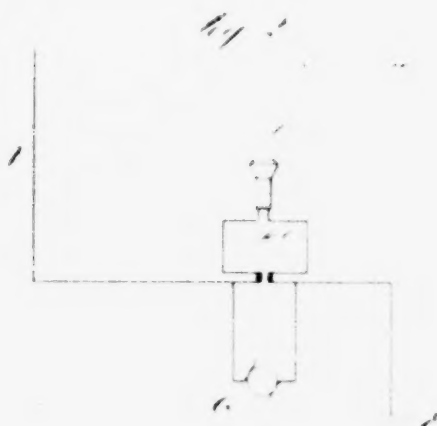
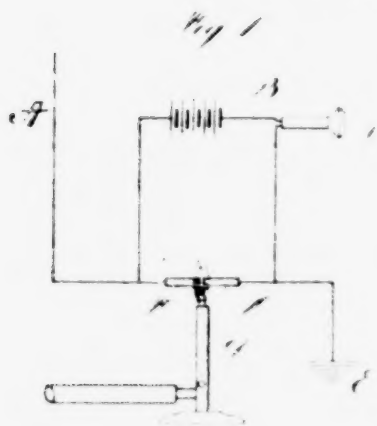
PLAINTIFF'S EXHIBIT 327 (7)

3221

L. DE FOREST.  
OSCILLATION RESPONSIVE DEVICE.  
APPLICATION FILED FEB 2 1905

979,275.

Patented Dec. 20, 1910.



WITNESSES

Frank H Parker  
John Buckler

INVENTOR

Lee de Forest  
by George Woodworth  
Associate Attorney

## UNITED STATES PATENT OFFICE.

LEE DE FOREST, OF NEW YORK, N. Y. ASSIGNOR, BY MESNE ASSIGNMENTS, TO DE FOREST RADIO TELEPHONE CO., A CORPORATION OF NEW YORK.

## OSCILLATION-RESPONSIVE DEVICE.

979,275.

Specification of Letters Patent.

Patented Dec. 20, 1910.

Application filed February 2, 1905. Serial No. 243,913.

*To all whom it may concern:*

Be it known that I, LEE DE FOREST, a citizen of the United States of America, and a resident of the borough of Manhattan, city, county, and State of New York, have invented certain new and useful Improvements in Oscillation-Responsive Devices, the principles of which are disclosed in the following specification and accompanying drawings, which explain the form of the invention which I now consider to be the best of the various forms in which the principles of the invention may be embodied.

My invention relates to an improvement in the sensitive member used in systems of wireless telegraphy to detect the electrical waves or oscillations and comprises the novel features hereinafter shown and described and particularly pointed out in the claims.

In the accompanying drawings I have shown, and in the description thereof will point out, certain forms of construction which may be employed in carrying out my invention and in connection therewith I will point out the principle of my invention.

Although by no means all the known or possible embodiments of my invention are here illustrated or described, sufficient is given to make clear the principle of my invention.

Figures 1 to 6 inclusive each represents a receiving set for a wireless telegraph system, each having a sensitive member differing in appearance but all embodying the principle of my invention.

I have discovered that if two bodies adapted for use as electrodes or conductive members, be electrically separated partially or wholly, after the manner common in analogous devices, the separation between them may be neutralized sufficiently to enable them to act as a detector of electrical oscillations, if the intervening or surrounding medium be put into a condition of molecular activity, such for instance as would be caused by heating it in any manner, as by radiation, conduction, or by the ionization of gases in the space which surrounds the poles. Such condition or molecular activity causes what would otherwise be a non-sensitive device to become sensitive to the reception of electrical influences. I am thus enabled to employ as such sensitive member, devices which would otherwise be of no value, or to make those devices now

used more sensitive to the electrical waves. This principle is embodied in the apparatus illustrated in the various figures shown.

In each of these figures, A represents the antenna or receiving conductor, or wave intercepting means; E, the earth connection; F, F', F'', F''', F'', and F', the electrodes used in their various forms; B, the local battery; and T, the receiving or indicating instrument, which is herein shown as a telephone receiver, the same being shown only as typical of any form of indicating apparatus capable of being employed for such purposes.

In Fig. 1 the two electrodes F, F', are slightly separated and are within the flame 70 of an ordinary Bunsen burner D. Under these conditions the electrodes may be adjusted so that there is normally no indication of a passing current given by the receiving instrument, such as the telephone 75 T. The electrical separation of the electrodes is however insufficient to prevent electrical oscillations from jumping the gap. The influence of these oscillations upon the heated gas seems to break down or lower 80 the insulating quality of the gap, so that, while the influence of the oscillations lasts, the current of the local circuit may pass between the electrodes, thus affecting the indicating instrument therein to produce a signal. This may be due to ionization of the gases surrounding the electrodes which greatly increases their conductivity, said ionization being more or less accomplished or greatly facilitated by their previous heat 85 ing which has already put them into a condition of intense molecular activity.

In Fig. 2 the electrodes F', F'', are of sufficiently great resistance to be heated by a current from a dynamo G, and by their 95 radiation heat the gas between them. This gas may be air or the electrodes may be inclosed and surrounded by any suitable gas as shown, for example, in Fig. 6 in which said electrodes are inclosed in the receptacle 100 H. The heating of the gas may also be by radiation from the electrodes F', F''.

In Fig. 3, the electrodes assume the form of two parallel plates F', F'', which are heated by a Bunsen burner. Although I 105 have shown a Bunsen burner for this purpose, this particular heating device is not essential, as any means of heating may be employed.

In Fig. 4 the burner itself is made one 110

of the electrodes, the other of which is shown at  $F^3$ .

In Fig. 5 the local circuit is provided with electrodes  $F^4$ ,  $F^4$ , and the oscillation-receiving circuit with separate electrodes  $F^5$ ,  $F^5$ , both being heated by the flame of the Bunsen burner. The effect in this case is the same as before stated, that is the passage of the oscillations enables the current of the local circuit to jump the gap between the electrodes  $F^4$ ,  $F^4$  and thus to operate the receiving instrument. The oscillations apparently ionize the gas and thus temporarily reduce its insulating power or in other words increase its conductivity and enable the current of the local circuit to overcome the resistance between its poles. The action described may be effected by controlling the composition of the gases between, and surrounding the electrodes or poles of the sensitive member. As an instance of this the addition of sodium or salts of the halogen class in the flame increases the ionization and conductivity of the gases and increases the sensitiveness of the device. Such control of the gases I consider to be within the scope of my invention.

While I have shown and described various means for securing this result I am aware that not all the possible means have been mentioned. Sufficient have however been described to indicate of what my invention consists. Any means for producing a heated gas with properly dissociated and conducting ions may be used.

I claim:

1. In a wireless telegraph system, the combination with separated electrodes connected to a wave intercepting means and to a local circuit, said electrodes being separated by a dielectric; of means cooperating with the received electrical oscillations for causing abnormal molecular activity in the intervening dielectric.

2. In a wireless telegraph system, the combination with separated electrodes connected to wave intercepting means and to a local circuit, said electrodes being separated by a dielectric; of means other than the received electrical oscillations, for heating the intervening dielectric.

3. In a wireless telegraph system, the combination with separated electrodes connected to a wave intercepting means and to a local circuit, said electrodes being separated by a dielectric; of a flame in the intervening dielectric.

4. In a wireless telegraph system, the combination with separated electrodes connected to a wave intercepting means and to a local circuit, said electrodes being separated by a dielectric; of means other than the received electric oscillations for changing the insulating quality of the intervening dielectric for the current of the local circuit.

5. In a wireless telegraph system, the combination with separated electrodes connected to a wave intercepting means and to a local circuit, said electrodes being separated by a dielectric; of means other than the received electrical oscillations, for changing the conductivity for the current of the local circuit, of the intervening dielectric.

6. In a wireless telegraph system, the combination with separated electrodes connected to a wave intercepting means and to a local circuit, said electrodes being separated by a dielectric; of a flame in the intervening dielectric, and a substance in the flame for increasing the conductivity of the gases.

7. In a wireless telegraph system, the combination with separated electrodes connected to a wave intercepting means and to a local circuit, said electrodes being separated by a dielectric; of means other than the received electrical oscillations, for maintaining a heated gas in the dielectric.

8. A sensitive detector for electrical oscillations, which comprises two electrodes and means for maintaining a heated gas therebetween.

9. A sensitive detector for electrical oscillations, which comprises two electrodes separated by a flame.

10. The combination with a detector of electrical oscillations, having separated electrodes, of means for maintaining between said electrodes, media in abnormal molecular activity.

11. The combination with a detector of electrical oscillations, having separated electrodes, of means for heating the intervening medium, and a substance in such heated medium which increases the conductivity thereof.

12. In a system of wireless or space telegraphy, the combination with intercepting means at a receiving station for intercepting electric waves transmitted through space from a transmitting station, of a detector in cooperative relationship with said wave intercepting means, for detecting the feeble oscillations caused by the intercepted waves to traverse said wave interceptor; a local circuit in cooperative relationship with said detector; an indicating device and a source of electromotive force cooperatively associated with said local circuit; said detector comprising two electrodes separated by an intervening dielectric, whereby both the received oscillations traversing said wave intercepting means and said local source of electromotive force, are normally inoperative with respect to said detector and indicating device; and means for establishing a heated gas in the space of separation between the electrodes of said detector, to permit the received oscillations to traverse such space and to thereby cause the local circuit of the local source of electromotive force to

operate said indicating device when oscillations are caused in the wave intercepting means by transmitted waves.

13. In a system of wireless or space telegraphy, the combination with intercepting means at a receiving station for intercepting electric waves transmitted through space from a transmitting station, of a detector in cooperative relationship with said wave intercepting means, for detecting the feeble oscillations caused by the intercepted waves to traverse said wave interceptor; a local circuit in cooperative relationship with said detector; an indicating device and a source of electromotive force cooperatively associated with said local circuit; said detector comprising two electrodes separated by an intervening dielectric, whereby both the received oscillations traversing said wave intercepting means and said local source of electromotive force, are normally inoperative with respect to said detector and indicating device; a gas burner, and means for conveying a supply of gas thereto, said burner being arranged so that its flame will intervene in the space of separation between the electrodes of said detector, to permit the received oscillations to traverse such space and to thereby cause the local circuit of the local source of electromotive force to operate said indicating device when oscillations are caused in the wave intercepting means by transmitted waves.

14. In a system of wireless or space telegraphy, the combination with intercepting means at a receiving station for intercepting electric waves transmitted through space from a transmitting station, of a detector in cooperative relationship with said wave intercepting means, for detecting the feeble oscillations caused by the intercepted waves to traverse said wave detector; a local circuit in cooperative relationship with said detector; an indicating device and a source of electromotive force cooperatively associated with said local circuit; said detector comprising two electrodes separated by an intervening dielectric, whereby both the received oscillations traversing said wave intercepting means and said local source of electromotive force, are normally inoperative with respect to said detector and indicating device; a burner, and means for conveying a supply of combustible matter thereon, said burner being arranged so that its flame will intervene in the space of separation between the electrodes of said detector, to permit the received oscillations to traverse such space and to thereby cause the local circuit of the local source of electromotive force to operate said indicating device when oscillations are caused in the wave intercepting means by transmitted waves.

15. In a system of wireless or space telegraphy, the combination with intercepting

means at a receiving station for intercepting electric waves transmitted through space from a transmitting station, of a detector in cooperative relationship with said wave intercepting means, for detecting the feeble oscillations caused by the intercepted waves to traverse said wave interceptor; a local circuit in cooperative relationship with said detector; an indicating device and a source of electromotive force cooperatively associated with said local circuit; said detector comprising two electrodes separated by an intervening dielectric, whereby both the received oscillations traversing said wave intercepting means and said local source of electromotive force, are normally inoperative with respect to said detector and indicating device; and means for establishing a heated gas in the space of separation between the electrodes of said detector, to permit the received oscillations to traverse such space and to thereby cause the local circuit of the local source of electromotive force to operate said indicating device when oscillations are caused in the wave intercepting means by transmitted waves; and a substance in said space of separation, which cooperates with the heated gas to increase the conductivity thereof.

16. In a system of wireless or space telegraphy, the combination at a receiving station with a detector of feeble oscillations caused by transmitted electromagnetic waves; of a circuit for said detector, which includes a source of electromotive force and an indicating device; said detector comprising two electrodes separated by an intervening dielectric, whereby both the received oscillations and source of electromotive force are normally inoperative with respect to said detector and indicating device; and means for establishing a heated gas in the space of separation between the electrodes of the detector, to permit the received oscillations to traverse said space and to thereby cause the circuit of the source of electromotive force to operate said indicating device when oscillations are received.

17. The combination with a detector of electrical oscillations of space telegraphy, said detector having electrodes separated by a dielectric, of means for heating the intervening dielectric, and a substance in said intervening dielectric which cooperates with said heating means to increase the conductivity of said dielectric.

18. An oscillation responsive device, comprising a gaseous medium, means for increasing the electrical conductivity of said gaseous medium, means for suppressing electrical oscillations upon said medium, the means operatively causing the conductivity responsive to variations in the conductivity thereof.

19. An oscillation responsive device, com-

prising a gas, means for putting said gas in a condition of molecular activity, means for impressing electrical oscillations upon said gas and means operatively connected therewith and responsive to alterations in the conductivity thereof.

20. An oscillation responsive device comprising a gaseous medium and means for heating said medium.

21. An oscillation responsive device comprising a gaseous medium and means for putting said medium in a condition of molecular activity.

22. An oscillation responsive device comprising a sensitive gaseous conducting medium containing a halogen salt.

23. An oscillation responsive device comprising a sensitive gaseous conducting medium containing a halogen salt and means for heating said medium.

24. An oscillation responsive device comprising a sensitive gaseous conducting medium containing a sodium salt.

25. An oscillation responsive device comprising a sensitive gaseous conducting medium containing a sodium salt and means for heating said medium.

26. An oscillation responsive device comprising a sensitive gaseous conducting medium containing a halogen salt and means for putting said medium in a condition of molecular activity.

27. An oscillation responsive device comprising a sensitive gaseous conducting medium containing a sodium salt and means for putting said medium in a condition of molecular activity.

28. An oscillation responsive device comprising a gaseous medium and means for rendering said gaseous medium sensitive to electrical oscillations.

29. An oscillation responsive device comprising a gaseous medium and means for increasing the conductivity of the said gaseous medium to such an extent as to render the same sensitive to electrical oscillations.

30. A self-restoring, constantly-receptive oscillation responsive device comprising in its construction a sensitive conducting gaseous medium.

31. A sensitive receiving member for wire-

less telegraphy having two poles separated by heated gas.

32. A sensitive receiving member for wireless telegraphy having two poles and means for surrounding the same with a heated gas.

33. A sensitive receiving member for wireless telegraphy having two poles surrounded by a flame.

34. A sensitive receiving member for wireless telegraphy employing a heated gas as a part of its conductive system.

35. In a sensitive receiving member for wireless telegraphy, the combination with two separated poles, of means for producing a condition of intense molecular activity in the medium intervening between said poles.

36. The combination with a sensitive receiving member for wireless telegraphy, of two separated poles and means for surrounding said poles with a medium which is continuously in a condition of intense molecular activity.

37. The combination with a sensitive receiving member for wireless telegraphy, of means for heating the medium intervening between the poles of said sensitive member and for introducing in said medium a substance adapted to increase its conductivity.

38. A sensitive receiving member for wireless telegraphy employing a gas maintained in a condition of molecular activity as a part of its conductive system.

39. In a sensitive receiving member for wireless telegraphy, the combination with separated poles, of means maintaining a condition of molecular activity in the medium intervening between said poles.

40. A wave detector having an electro-radiant wave detecting circuit including electrodes separated by an unconfined gaseous medium.

41. A wave detector having an electro-radiant wave detecting circuit formed in part by a body of free gaseous particles.

Borough of Manhattan, city and county of New York, November 4, 1904.

LEE DE FOREST.

Witnesses:

PHILIP FARNSWORTH,  
JULIET SCHWABACH.

# PLAINTIFF'S EXHIBIT 335

## CHAPTER III. COUPLED CIRCUITS.

239

**General.** When there is a transfer of power from one circuit to another circuit, it is said that the two circuits are coupled. This transfer of power can be accomplished by electromagnetic or electric induction, or by resistance coupling. The coupling between circuits whether it is resistance, electromagnetic (inductive), or electric (capacitive), is divided into two classes, i.e., the direct and the indirect coupling.

Direct coupling refers to circuits where the coupling element is common to both circuits, whether it is an inductance, a capacity or a resistance. See figures 144, 145 and 146.



FIG. 144.—Direct Coupling by Inductance



FIG. 145.—Direct Coupling by Capacity.



FIG. 146.—Direct Coupling by Resistance.

Indirect coupling is accomplished between circuits by magnetically coupling the inductances of each circuit or by capacitive coupling using condensers between the circuits, as shown in figures 147 and 148.



FIG. 147.

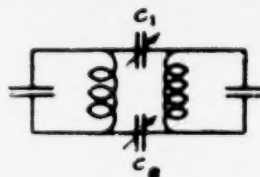


FIG. 148.

In figure 147, the transfer of power is accomplished magnetically and this power is proportioned to the distance between the two inductances, the closer the inductances the greater the transfer, while the farther apart the inductances are, the smaller the transfer. In other words, the closer the inductances the greater the electromagnetic induction while the farther apart the inductances are the smaller the electromagnetic induction.

Figure 148 shows a method of indirectly coupling circuits by capacities. An increase in the value of the coupling capacities ( $C_1$  and  $C_2$ ) will increase the amount of power transferred from one circuit to another, while a decrease will reduce the power transfer.

In both methods of indirect coupling referred to, it is customary to refer to the condition of maximum power transfer as **tight coupling** and the condition of minimum power transfer as **loose coupling**. Coupling and coefficient of coupling are explained in detail in Chapter 7, Part 2.

If the coupling between two circuits is small, the two circuits will be resonant to one frequency but if the coupling is increased, both circuits, due principally to the effect of mutual inductance, will no longer be resonant to the original frequency, but will be resonant to two frequencies, one frequency being lower than the original frequency and the other being higher than the original frequency. With loose coupling it is possible to have each circuit resonant to one frequency, while if the coupling is tightened or increased in value, each circuit will be resonant to two frequencies.

The difference in frequencies referred to is dependent on the degree of coupling.

Figure 149 shows the resonance curve for a typical circuit when loosely coupled to another circuit, while figure 150 shows the same circuit under influence of a tight coupling.

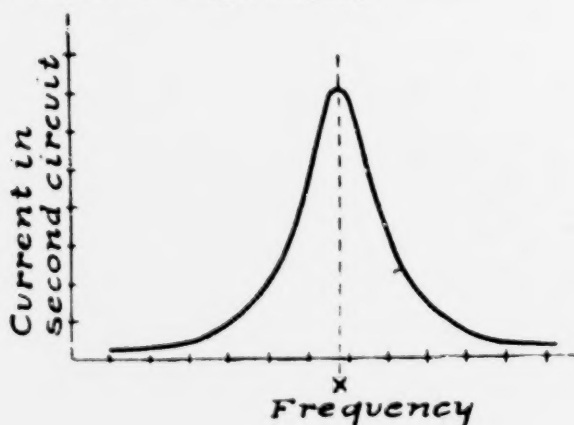


FIG. 149

In figure 149,  $X$  represents the resonant frequency of the circuit, while  $X_1$  and  $X_2$  in figure 150 are the two frequencies to which the circuit is resonant when affected by tight coupling.

The question naturally arises why are the circuits resonant to two frequencies? The two circuits are resonant to two frequencies because of the fact that the mutual inductance of the circuits momentarily adds or subtracts from the inductance of each circuit.

The value of the inductance in each circuit varies momentarily and the circuits are resonant to two frequencies. The difference in

the two frequencies depends on the value of mutual inductance or, in other words, on the coupling between the circuits. This may be represented

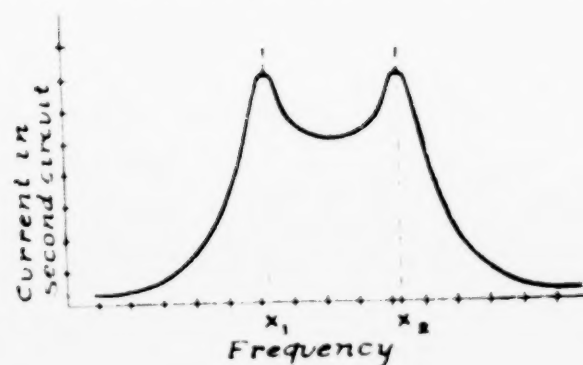


FIG. 150

by the following *LC* equations which, in turn, have a definite relation to the frequency and wave length to which the circuits are resonant.

For loose coupling 
$$f = \frac{1}{2\pi\sqrt{LC}}$$

For tight coupling 
$$f_1 = \frac{1}{2\pi\sqrt{(L+M)C}}$$

and

$$f_2 = \frac{1}{2\pi\sqrt{(L-M)C}}$$

where

$$M = k\sqrt{L_1 L_2}$$

$L_1$  being inductance of one circuit and  $L_2$  the inductance of the other circuit.

When the coefficient of coupling is known, the two periods of resonance of the coupled circuits are found by the following:

$$\lambda_1 = \lambda\sqrt{1+k}$$

and

$$\lambda_2 = \lambda\sqrt{1-k}$$

where  $\lambda$  is the wave length to which the circuit is resonant to when acting singly, or very loosely coupled.

This phenomena of coupling and resonance of the circuits produces an effect in a spark transmitter where signals on **two wave lengths are transmitted** when tight or medium coupling is resorted to. In vacuum-tube or other undamped transmitters, although the two resonant fre-

[fol. 2814]

## PLAINTIFF'S EXHIBIT 343

At a Stated Term of the United States District Court for the Eastern District of New York, held in the Post Office Building in the Borough of Brooklyn, City of New York, on the 6th day of April, 1914.

Present: Hon. Van Vechten Veeder, United States Judge.

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Complainant,

vs.

NATIONAL ELECTRIC SIGNALING COMPANY, Defendant

In Equity No. DE 31. On Marconi Patent No. 763,772

This cause having come on to be heard at final hearing upon pleadings and proofs taken and filed on behalf of both parties herein, and counsel for the respective parties having been heard, and due consideration having been had, it is, upon motion of Sheffield, Bentley & Betts, solicitors for the complainant Ordered, Adjudged and Decreed as follows:

1. That Letters Patent of the United States in suit, issued to Guglielmo Marconi on June 28, 1904, No. 763,772, for "Apparatus for Wireless Telegraphy", are good and valid in law as to the 1st, 2nd, 3rd, 6th, 8th, 10th, 11th, 12th, 13th, 14th, 16th, 17th, 18th, 19th, and 20th claims thereof, which are as follows:

"1. At a station employed in a wireless telegraph system, a signaling instrument comprising an induction coil, the secondary circuit of which includes a condenser discharging [fol. 2815] through a means which automatically causes oscillations of the desired frequency; an open circuit electrically connected with the oscillation-producer aforesaid and a variable inductance included in the open circuit, substantially as and for the purpose described.

"2. At a station employed in a wireless-telegraph system, an oscillation-receiving conductor, a variable inductance connected with said conductor; a wave responsive device electrically connected with said conductor and in circuit with a condenser, substantially as and for the purpose described.

"3. At a station employed in a wireless-telegraph system, a signaling instrument comprising an induction-coil, the secondary circuit of which includes a condenser discharging through a means which automatically causes oscillations of the desired frequency, and the primary circuit of which includes a generator; means for varying the primary circuit; an open circuit electrically connected with the oscillation-producer aforesaid, and a variable inductance included in the open circuit, substantially as and for the purpose described.

"6. At a transmitting station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating conductor at one end and capacity at the other end, and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, and means for adjusting the oscillation period of each of the two circuits connected with the transformer to bring them into accord with each other, substantially as described.

"8. At a transmitting-station employed in a wireless-telegraph system, the combination of a transformer whose secondary is connected to an open circuit including a radiating-conductor at one end and capacity at the other end, a variable inductance being included in said circuit, and whose primary is connected to a condenser-circuit discharging through a means which automatically causes oscillations of the desired frequency, substantially as described.

"10. A system of wireless telegraph~~y~~, in which the transmitting station and the receiving-station each contains an oscillation transformer, one circuit of which is an open circuit and the other a closed circuit, the two circuits at each station being in electrical resonance with each other and in electrical resonance with the circuit at the other station, substantially as described.

[fol. 2816] "11. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting station, of an induction coil; an electric circuit containing the secondary of said coil, a condenser and the primary coil of the oscillation transformer; a producer of electric waves of high frequency electrically connected with the secondary of the induction-

coil; a signaling instrument in circuit with the primary of the induction-coil; the secondary coil of the oscillation-transformer electrically connected, at one end to capacity and at the other end to an inductance, and an aerial conductor connected to the inductance, substantially as and for the purpose described.

"12. In apparatus for communicating electrical signals, the combination, with an oscillation-transformer, at a transmitting-station, of an induction-coil; an electric circuit containing the secondary of the said coil, a condenser and the primary coil of the oscillation-transformer; a producer of electric waves of high frequency connected with the secondary of the induction coil; a signaling instrument in circuit with the primary of the induction-coil; the secondary coil of the oscillation-transformer electrically connected, at one end to capacity and, at the other end, to a variable inductance, and an aerial conductor connected to the variable inductance, substantially as and for the purpose described.

"13. At a receiving station employed in a wireless-telegraph system, the combination of an oscillation transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a variable inductance being included in said circuit, a wave-responsive device electrically connected with the other windings of the oscillation-transformer, and a condenser in circuit with the wave-responsive device, substantially as described.

"14. At a receiving station employed in a wireless telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave responsive device electrically connected with the other winding of the oscillation-transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described.

"16. At a receiving-station, employed in a wireless-telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at [2817] one end and capacity at the other end, an adjust-

able condenser in a shunt connected with the open circuit and around said transformer coil, a wave responsive device electrically connected with the other coil of the oscillation-transformer, and means for adjusting the two transformer-circuits in electrical resonance with each other, substantially as described.

“17. At a receiving station employed in a wireless telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end and capacity at the other end, a wave responsive device electrically connected with the other winding of the oscillation-transformer, and means included in each of said transformer circuits, for adjusting said circuits in electrical resonance with each other, substantially as described.

“18. At a receiving station employed in a wireless telegraph system, the combination of an oscillation-transformer, an open circuit connected with one coil of said transformer, said circuit including an oscillation-receiving conductor at one end, and capacity at the other end, a variable inductance being included in said open circuit, a wave-responsive device electrically connected with the other winding of the oscillation-transformer, and a variable inductance included in circuit with the wave responsive device, substantially as described.

“19. In a system of wireless telegraphy, the combination at a receiving station, of an oscillation-transformer; an open circuit comprising, in part, an aerial conductor connected with one end of the primary coil of the oscillation-transformer; a connection from the other end of said coil to capacity; a variable inductance in said open circuit; and electrical connections from the secondary coil of the oscillation-transformer to a receiving instrument, battery, condenser, wave responsive device and a variable inductance, substantially as and for the purpose described.

“20. In a system of wireless telegraphy, a transmitting station containing an oscillation transformer, the primary of which is connected to a condenser-circuit discharging through a spark gap which automatically causes electric waves of the desired frequency, the secondary of said transformer connected to an open circuit including a radiating-conductor, and with a capacity and a coil for charging the

condenser aforesaid; a receiving-station containing an oscillation-transformer, the primary of which is connected with an oscillation-receiving conductor and with a capacity, a wave-responsive device connected with the secondary of said transformer, and a receiving instrument connected [fol. 2818] with the wave-responsive device, all in combination with means for bringing the four transformer-circuits, two at each station, into electrical resonance with each other, substantially as described."

2. That the complainant, Marconi Wireless Telegraph Company of America, is the sole and exclusive owner of said Letters Patent.

3. That the said Guglielmo Marconi was the first, true, original and sole inventor of the inventions described in said Letters Patent and claimed in said claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 16, 17, 18, 19 and 20 of said Letters Patent No. 763,772.

4. That the defendant, National Electric Signaling Company, has infringed upon said claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 16, 17, 18, 19 and 20 of said Letters Patent No. 763,772, by manufacturing, selling and using, or causing to be manufactured, sold or used, apparatus containing, embodying or employing the inventions of said claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 16, 17, 18, 19 and 20 of said Letters Patent.

5. That the complainant do recover of the defendant the profits, gains and advantages which the defendant has derived, received, earned or made, or which it shall derive, receive, earn or make by reason of the aforesaid or any infringement of the said 1st, 2nd, 3rd, 6th, 8th, 10th, 11th, 12th, 13th, 14th, 16th, 17th, 18th, 19th and 20th claims of said Letters Patent No. 763,772, and that the complainant do recover of the defendant any and all damages which the complainant has sustained or shall sustain by reason of the aforesaid or any infringement of the said 1st, 2nd, [fol. 2819] 3rd, 6th, 8th, 10th, 11th, 12th, 13th, 14th, 16th, 17th, 18th, 19th and 20th claims of said Letters Patent No. 763,772; and it is hereby referred to Richards M. Cahoon, Esq., as a Master of this Court, to take and state an account of said gains, profits and advantages and to assess such damages and to report to the Court thereon with all con-

venient speed; and the said defendant, its directors, officers, receivers, agents and employees, are directed and required to attend before said Master from time to time as required, and to produce before him such apparatus, books, documents, vouchers, and papers, and to submit to such oral examination or otherwise as the said Master may require in connection with said accounting and the assessing of said damages.

6. That a perpetual injunction issue out of and under the seal of this Court directed to the said defendant, National Electric Signaling Company, its associates, directors, officers, receivers, attorneys, solicitors, clerks, servants, agents, workmen and employees, enjoining and restraining them and each of them from directly or indirectly making or causing to be made, using or causing to be used, selling or causing to be sold, renting or leasing to others to be used, or disposing of in any manner whatsoever, threatening to make, sell, lease or use, advertising or offering for sale, lease or use, contributing to the manufacture, sale or use [fol. 2820] in any manner whatsoever, of apparatus, devices or appliances containing, embodying or employing the inventions of said claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 16, 17, 18, 19 and 20 of said Letters Patent No. 763,772 or any material or substantial part thereof, or from infringing upon or violating or from contributing to the infringement or violation of said claims, or either or any of them, or any material or substantial part thereof, in any way whatsoever.

7. That the complainant do recover of the said defendant, National Electric Signaling Company, the costs and disbursements of this suit to be taxed, and that the question of increase of damages and all further questions be reserved until the coming in of the Master's report.

(sgd.) Van Vechten Veeder, United States Judge.

(Clerk's certificate attached.)

[fol. 2821]

## PLAINTIFF'S EXHIBIT 344

At a Stated Term of the United States District Court held in the Court Rooms in the Borough of Brooklyn, City of New York, on the 18th day of November 1914.

Present Hon. Van Vechten Veeder, U. S. Judge.

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

vs.

NATIONAL ELECTRIC SIGNALING COMPANY and SAMUEL M.  
KINZNER and HALSEY M. BARRETT, Receivers of Said Com-  
pany, Defendants.

In Equity. D E 31

On Marconi Patent No. 763,772

This cause having come on to be further heard at this term of the Court, and a certified copy of the order entered in the United States Circuit Court of Appeals for the Second Circuit on November 18th, 1914, dismissing the defendants' appeal from the interlocutory decree entered herein on April 6, 1914, having been filed herein on November 18th, 1914, and it appearing that a settlement has been made between the parties hereto, it is upon consideration, the consent of both parties and the motion of Sheffield, Bentley & Betts, solicitors for the plaintiff,

Ordered, Adjudged and Decreed that the said order of the Circuit Court of Appeals be and the same hereby is made the order of this Court, and that the said interlocutory decree entered herein on April 6, 1914, and all the provisions [fol. 2822] thereof, except that directing the recovery by the plaintiff from the defendant of damages, profits, gains and advantages for the infringement of the Marconi patent in suit No. 763,772, and ordering an accounting and assessment thereof, be and hereby are affirmed and made final herein, with costs and disbursements to the plaintiff.

Van Vechten Veeder, U. S. Judge.

We hereby approve the foregoing decree as to form and consent to the entry thereof.

Sheffield, Bentley & Betts, Plaintiff's Solicitors,  
Herbert G. Ogden, Defendants' Solicitor,

At a Stated Term of the United States District Court for the Southern District of New York, Borough of Manhattan, City of New York, on the 9th day of October, 1916.

Present Hon. Julius M. Mayer, U. S. D. J.

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY and LEE  
DEFOREST, Defendants

In Equity No. 12-31.      On Fleming aPatent No. 803,684

#### INTERLOCUTORY DECREE

This cause having come on to be heard at final hearing, upon the pleadings and proofs taken and filed on behalf of both parties herein, and counsel for the respective parties having been heard, and due consideration having been had, it is, upon motion of Sheffield & Betts, solicitors for the plaintiff,

Ordered, Adjudged and Decreed as follows:

1. That the plaintiff, the Marconi Wireless Telegraph Company of America, is the sole and exclusive owner of United States Letters Patent No. 803,684, to John Ambrose Fleming, dated November 7, 1905.

2. That said Letters Patent No. 803,684 to John Ambrose [fol. 2824] Fleming are good and valid in law as to the first and thirty-seventh claims thereof, which are as follows:

"1. The combination of a vacuum vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, and a circuit outside the vessel connecting the two conductors.

"37. At a receiving station in a system of wireless telegraphy employing electrical oscillations of high frequency, a detector comprising a vacuum vessel, two conductors adjacent to but not touching each other in the vessel, means for heating one of the conductors, a circuit outside of the vessel connecting the two conductors, means for detecting a continuous current in the circuit, and means for impressing upon the circuit the received oscillations."

3. That the said John Ambrose Fleming was the first, true, original and sole inventor of the inventions described in said Letters Patent and claimed in said claims 1 and 37 of said Letters Patent No. 803,684.

4. That the defendant, DeForest Radio Telephone & Telegraph Company, has infringed upon said claims 1 and 37 of said Letters Patent No. 803,684, by manufacturing, selling and using, or causing to be manufactured, sold or used, apparatus containing, embodying or employing the inventions of said claims 1 and 37 of said Letters Patent.

5. That a perpetual injunction issue out of and under the seal of this Court, directed to the defendant DeForest Radio [fol. 2825] Telephone & Telegraph Company and its associates, officers, directors, attorneys, clerks, servants, agents, workmen and employees, enjoining and restraining them and each of ~~them~~ from directly or indirectly making or causing to be made, using or causing to be used, leasing or causing to be leased, selling or causing to be sold, advertising or offering for sale, use or lease, or causing to be advertised or offered for sale, use or lease, agreeing or contracting to sell or lease, or causing to be agreed or contracted for sale or lease, supplying or causing to be supplied, installing or causing to be installed, or threatening to make, use, lease, sell, supply or install, and threatening to offer or contract for sale, lease or supply, or disposing of in any manner, any devices, structures, appliances, instruments or wireless telegraph apparatus embodying or employing the said inventions and improvements or discoveries of the said 1st and 37th claims of said Letters Patent No. 803,684, or either of them, and from infringing upon or contributing to the infringement of said claims 1st and 37th of said Letters Patent, or either of them, in any way whatsoever.

6. That the defendant, DeForest Radio Telephone & Telegraph Company, is the sole and exclusive owner of the United States Letters Patent pleaded in the defendant's counterclaim, to Lee DeForest, as follows:

Nos. 824,637, dated June 26, 1906;  
836,070, dated November 13, 1906;  
837,901, dated December 4, 1906;  
841,386, dated January 15, 1907; /

[fol. 2826] Nos. 841,387, dated January 15, 1907;  
 867,876, dated October 8, 1907;  
 867,877, dated October 8, 1907;  
 867,878, dated October 8, 1907;  
 879,532, dated February 18, 1908, and  
 979,275, dated December 20, 1910.

7. That said Letters Patent No. 841,387 to Lee DeForest are good and valid in law as to the 4th and 6th claims thereof, which are as follows:

"4. In a device for amplifying electrical currents, an evacuated vessel, three electrodes sealed within said vessel, means for heating one of said electrodes, a local receiving-circuit including two of said electrodes, and means for passing the current to be amplified between one of the electrodes which is included in the receiving-circuit and the third electrode.

"6. In a device for amplifying electrical currents, an evacuated vessel, a heated electrode and two non-heated electrodes sealed within said vessel, the non-heated electrodes being unequally spaced with respect to said heated electrode, a local receiving circuit including said heated electrode and that one of the non-heated electrodes which has the greater separation from the heated electrode, and means for passing the current to be amplified between the heated electrode and the other non-heated electrode."

8. That the said Lee DeForest was the first, true, original and sole inventor of the inventions described in said Letters Patent No. 841,387, and claimed in claims 4 and 6 thereof.

9. That said Letters Patent No. 879,532, dated February 18, 1908, are good and valid in law as to claims 2, 3, 6, 14, 18 and 21 thereof, which are as follows:

"2. An oscillation detector comprising an evacuated vessel, two electrodes inclosed within said vessel, means for heating one of said electrodes, and a conducting member inclosed within said vessel and interposed between said electrodes.

[fol. 2827] "3. An oscillation detector comprising an evacuated vessel, two electrodes inclosed within said vessel, means for heating one of said electrodes, and a grid shaped member of conducting material inclosed within said vessel and interposed between said electrodes.

"6. An oscillation detector comprising an evacuated vessel, two electrodes inclosed therein, means for heating one of said electrodes, a conducting member inclosed within said vessel and interposed between said electrodes, means for establishing a difference of electrical potential between said electrodes and means for preventing said conducting member from becoming electrically charged.

"14. An oscillation detector comprising an evacuated vessel, two electrodes, one of which is a filament, inclosed within said vessel, means for heating said filament, and a conducting member inclosed within said vessel and interposed between said electrodes.

"18. An oscillation detector comprising an evacuated vessel, two electrodes inclosed within said vessel, means for heating one of said electrodes, a grid of conducting material inclosed within said vessel and interposed between said electrodes, a local circuit including a source of electromotive force connecting said electrodes and a signal indicating device associated with said local circuit.

"21. An oscillation detector comprising an evacuated vessel, two electrodes inclosed therein, means for heating one of said electrodes, a conducting member inclosed within said vessel, a closed oscillation circuit, a circuit connecting one element of said oscillation circuit with one of said electrodes and said conducting member, a condenser in said circuit, a signal indicating device and a circuit connecting said device with the other of said electrodes and said conducting member."

10. That the said Lee DeForest was the first, true, original and sole inventor of the inventions described in said Letters Patent No. 879,532, and claimed in claims 2, 3, 6, 14, 18 and 21 thereof.

11. That a perpetual injunction issue out of and under the seal of this Court directed to the plaintiff, Marconi [fol. 2828] Wireless Telegraph Company of America, and its associates, officers, attorneys, clerks, servants, agents, workmen and employees, enjoining and restraining them, and each of them, from directly or indirectly making or causing to be made, using or causing to be used, leasing or causing to be leased, selling or causing to be sold, advertising or offering for sale, use or lease, or causing to be advertised or offered for sale, use or lease, agreeing or contract-

ing to sell or lease, or causing to be agreed or contracted for sale or lease, supplying or causing to be supplied, installing or causing to be installed, or threatening to make, use, lease, sell, supply or install, or threatening to offer or contract for sale, lease or supply, or disposing of in any manner, any devices, structures, appliances, instruments or wireless telegraph apparatus embodying or employing the said inventions and improvements or discoveries of said claims 4 and 6 of said Letters Patent No. 841,387, and claims 2, 3, 6, 14, 18 and 21 of said Letters Patent No. 879,532, or any of them, and from infringing upon or contributing to the infringement of said claims of said Letters Patent in any way whatsoever.

12. That the plaintiff, Marconi Wireless Telegraph Company of America, do recover of the defendant, DeForest Radio Telephone & Telegraph Company, the profits, gains and advantages which the defendant has derived, received, earned or made, or which it shall derive, receive, earn or make by reason of the aforesaid or any infringement of the [Feb. 28-29] 1st and 37th claims of said Fleming Patent No. 803,684; and that the plaintiff do recover of the defendant any and all damages the plaintiff has sustained or shall sustain by reason of the aforesaid infringement of the said 1st and 37th claims of said Fleming patent No. 803,684; and that the defendant, DeForest Radio Telephone & Telegraph Company, do recover of the plaintiff the profits, gains and advantages which the plaintiff has derived, received, earned or made, or shall derive, receive, earn or make by reason of the aforesaid or any infringement of the said 4th and 6th claims of United States Letters Patent No. 841,387 and claims 2, 3, 6, 14, 18 and 21 of United States Letters Patent No. 879,532; and that the defendant do recover of the plaintiff any and all damages which the defendant has suffered or shall sustain by reason of the aforesaid or any infringement of the 4th and 6th claims of said Letters Patent No. 841,387 and claims 2, 3, 6, 14, 18 and 21 of United States Letters Patent No. 879,532; and it is hereby referred to George C. Holt, Esq., as a Master of this Court, to take and state an account of said gains, profits, and damages, and to assess such damages and to report thereon to the Court with all convenient speed; and the said plaintiff and the said defendant and their directors, officers, agents and employees are directed and required to attend before said Master from

time to time as required and to produce before him such apparatus, books, documents and papers, and to submit to such oral examination or otherwise as the said Master may require in connection with said accounting and the assessing of said damages.

[fol. 2830] 13. That the plaintiff's bill of complaint as against the defendant Lee DeForest individually be dismissed.

14. That the defendant's counterclaim against the plaintiff upon Letters Patent No. 824,637, No. 836,070, No. 837,901, No. 841,386, No. 867,876, No. 867,877, No. 867,878, No. 979,275, and as to claim 5 of said Letters Patent No. 841,387, be dismissed.

15-a. That the plaintiff, Marconi Wireless Telegraph Company of America, do recover of the defendant, DeForest Radio Telephone & Telegraph Company, the costs and taxable disbursements incurred in defending defendants' counterclaim.

b. That the defendant, DeForest Radio Telephone & Telegraph Company, do recover of the plaintiff the costs and taxable disbursements, if any, in connection with the sustaining of claims 4 and 6 of United States Letters Patent No. 841,387 and claims 2, 3, 6, 14, 18 and 21 of United States Letters Patent No. 879,532.

c. That the defendant Lee DeForest do recover of the plaintiff the costs which he individually is entitled to recover as an individual defendant.

Julius M. Mayer, U. S. District Judge.

[Endorsed:] U. S. District Court, S. D. of N. Y. Filed Oct. 9, 1916.

[fol. 2831]

PLAINTIFF'S EXHIBIT 348

UNITED STATES DISTRICT COURT, SOUTHERN DISTRICT OF  
NEW YORK

In Equity No. 12-31

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

vs.

DEFOREST RADIO TELEPHONE & TELEGRAPH COMPANY,  
Defendant

And Now, To Wit, this 18th day of July, 1917, upon the return of the order of this Court dated January 22, 1917, and the motion of the plaintiff, requiring the defendant, DeForest Radio Telephone & Telegraph Company, to show cause why the decree of this court, dated October 9, 1916, and the injunction issued in accordance therewith, restraining the defendant from infringing upon claims 1 and 37 of Fleming patent No. 803,684, do not cover and include certain devices heretofore manufactured and sold by the defendant; and upon consideration of the affidavit of Frank N. Waterman, verified January 18, 1917, filed in support of said order to show cause; and the affidavits of Lee DeForest and John Stone Stone, verified February 2, 1917, filed in opposition to said order to show cause; and the affidavits of Edwin H. Armstrong, Frank N. Waterman and Roy A. Weagant, verified April 18, 1917, filed in reply to said affidavits of DeForest and Stone and in further support of said order to show cause; and the affidavits of John Stone Stone and Robert F. Gowen, verified May 12, 1917, and of [fol. 2832] Charles V. Logwood and Walter A. Cohen, verified May 14, 1917, and of Lee DeForest, verified May 16, 1917, filed by the defendant in further opposition to the said order to show cause; and after hearing counsel for the respective parties, it is

Ordered, Adjudged and Decreed that, in addition to the devices or apparatus heretofore manufactured and sold by the defendant, and decreed to be an infringement of claims 1 and 37 of the Fleming patent in suit, that the devices or apparatus called by the defendant "amplifiers",

which have been manufactured and sold by the defendant separately, as well as the devices or apparatus which the defendant has manufactured and sold comprising "amplifiers" alone or in combination with other apparatus or instruments, are infringements of claims 1 and 37 of the Fleming patent in suit; and that any bulbs embodying claims 1 and 37 manufactured and sold by the defendant for use in such "amplifiers" or combination of "amplifiers" and other instruments or apparatus, are also an infringement of said claims 1 and 37 of the Fleming patent in suit, and that the injunction ordered to issue out of and under the seal of this Court by the interlocutory decree of October 9, 1916, shall cover and include each and all of such devices or pieces of apparatus, and that the defendant shall account to the plaintiff for all damages and profits which the plaintiff may be entitled to by reason of such infringing manufacture and sale, as provided for in the decree of October 9, 1916. [fol. 2833] And it is further Ordered, Adjudged and Decreed that the motion of the plaintiff with respect to the devices called by the defendant "oscillions," be and the same hereby is denied, without prejudice to the right of the plaintiff to renew said motion hereafter upon the filing of a new bill or a bill supplemental to the bill of complaint already filed. Future sales to U. S. Government are excepted from this order.

Julius Mayer, U. S. D. J.

Dated July 18, 1917.

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[fol. 2834] PLAINTIFF'S EXHIBIT 349

At a stated term of the United States District Court for the Southern District of New York, held in the United States Court Rooms, in the Borough of Manhattan, City and State of New York, on the 9th day of July, 1919.

Present: Hon. Julius M. Mayer, U. S. D. J.

In Equity No. 12-31. On Fleming Patent No. 803,684

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

vs.

DEFOREST RADIO TELEPHONE AND TELEGRAPH COMPANY,  
Defendant

This cause having come on to be further heard on the supplemental bill of complaint and answer and proofs taken

and filed on behalf of both parties herein and counsel for the respective parties having been heard and due consideration having been had, it is, upon motion of Sheffield & Betts, Solicitors for the Plaintiff,

Ordered, Adjudged and Decreed that in addition to the devices or apparatus heretofore manufactured and sold by the defendant and decreed to be an infringement of claim 1 of the Fleming patent No. 803,684, in suit, the devices or apparatus called by the defendant "oscillions" which have been manufactured and sold by the defendant separately, as well as the devices or apparatus which the defendant has manufactured and sold comprising "oscillions" alone or in combination with other apparatus or [fol. 2835] instruments are infringements of said claim 1 of the said Fleming patent in suit; and that any bulbs embodying said claim 1 manufactured and sold by the defendant for use in such "oscillions" or combination of "oscillions" and other instruments or apparatus, are also an infringement of said claim 1, of the said Fleming patent in suit; and that the injunction ordered to issue out of and under the seal of this Court by the Interlocutory Decree of October 9, 1916 and said Interlocutory Decree shall cover and include each and all of such devices or pieces of apparatus and that the defendant shall account to the plaintiff for all damages and profits to which the plaintiff may be entitled by reason of such infringing manufacture and sale as provided for in said Decree of October 9, 1916.

And It Is Further Ordered, Adjudged and Decreed that the plaintiff, Marconi Wireless Telegraph Company of America, do recover of the defendant, DeForest Radio Telephone and Telegraph Company, the costs and taxable disbursements in connection with said supplemental bill of complaint herein and the trial thereunder.

J. M. Mayer, U. S. District Judge.

It is hereby consented that the above order may be entered without further notice.

Sheffield & Betts, Plaintiff's Solicitors. Darby &  
Darby, Defendant's Solicitors.

[fol. 2836]

## PLAINTIFF'S EXHIBIT 363

House of Representatives

67th Congress, 1st Session

## Report No. 173

## Settlement of Damages for Infringements of Radio Patents

June 15, 1921.—Committed to the Committee of the Whole House on the state of the Union and ordered to be printed.

Mr. KAHN, from the Committee on Military Affairs, submitted the following Report. [To accompany H. R. 7111.]

The Committee on Military Affairs, to whom was referred the bill (H. R. 7111) authorizing the Secretary of War, the Attorney General, and the Secretary of the Navy jointly to make settlement of damages and compensation due by the United States for infringement of radio patents connected with the prosecution of the war, and for other purposes, having considered the same, report thereon with a recommendation that it do pass.

This bill was referred to the Committee on Military Affairs by the Speaker of the House in a communication signed, respectively, by the Secretary of War, the Attorney General, and the Secretary of the Navy, which reads as follows:

Departments of War, Justice, and Navy, *Washington, D. C.,*  
*May 11, 1921.*

DEAR MR. GILLET: We have the honor to invite attention to the situation that exists as a result of the use by the Government of patented inventions relating to radio communication and the development in that art.

Prior to the war with Germany the Government, principally the War and Navy Departments, found it necessary, because the validity of many patents relating to wireless telegraphy had not been judicially determined, to use wireless apparatus of various kinds without strict regard to the rights claimed by patentees, and during the war both departments used any and all apparatus, principles, and methods of known value without consideration of questions of infringement or proprietorship, giving where necessary

its warranty to contractors to protect them from litigation for infringement.

The development of this art has been very rapid and the patent situation with respect thereto is exceedingly complicated. There are many patents relating to the subject and a large number of claims for compensation for alleged use and infringement of patented inventions, among which there is much conflict, have been filed with the War and Navy Departments.

Realizing that the use by the Government had infringed the rights of many patentees while some of the claims possess little or no merit, and that a fair and reasonable determination of the whole matter would be difficult, long [fol-2837] drawn out and expensive to the Government as well as to the claimants if an adjustment were not arrived at by a reasonable and business-like consideration of the interests of all parties concerned, a board designated "Interdepartmental Radio Board" was appointed by ourselves consisting of experts from the War Department, Department of Justice, and the Navy Department to consider all such claims, each with reference to its own merits and the merits of all the others. Such board has been considering the matter for nearly three years, giving all questions connected therewith careful, intelligent, and exhaustive consideration.

The claims presented to the board totaled many millions of dollars. Out of the 24 claims brought only 7 stated the amount of the compensation desired, and the total of those 7 was \$14,800,000, the rest aggregating probably a much larger sum.

The board, giving due weight to matters of infringement, validity of patents, values of inventions, the circumstances of use by the Government, and the entire value of up-to-date wireless apparatus as the product of all inventions combined, has determined a sum of money that the Government should fairly and reasonably pay to the different patentees in proportion to the value of their respective inventions. Such sum will not exceed \$2,500,000, which is only a small percentage of the aggregate sum claimed.

The owners of the various patents affected have been informed of the board's determination, and many or all of them have signified a willingness to accept the amounts allotted to them. The work of the board has been most painstaking and careful, and its conclusions and determina-

tions reflect great credit upon its members. If settlement with the various patentees can be effected on the basis of the board's determination, a situation fraught with troublesome consequences would be disposed of to the great advantage of the Government and to the ultimate satisfaction of the claimants, and it is highly desirable, therefore, that provision be made for such settlements.

Therefore it is urgently recommended that the War, Justice, and Navy Departments be empowered to adjust and pay said claims on the basis of said board's determination.

Transmitted herewith is a draft of a provision that it is believed covers the matter adequately, and is suggested as an amendment to the act entitled "An act to provide relief in cases of contracts connected with the prosecution of the war, and for other purposes," approved February 2, 1919, commonly known as the Dent Act.

If at an early date payment could be tendered to all the claimants of the respective amounts found in their favor by said board, it is believed that all claimants having claims of substantial merit would accept settlement and release the Government, and it is earnestly requested that this matter be given favorable and prompt consideration by Congress.

Very sincerely, John W. Weeks, *Secretary of War*,  
H. M. Daugherty, *Attorney General*, Edwin Denby,  
*Secretary of the Navy*.

Hon. Frederick H. Gillett, *Speaker of the House of Representatives*.

The testimony before the committee discloses the fact that during the World War it became necessary for the Government of the United States to seize radio telegraphic and telephonic appliances as a war emergency measure regardless of the rights of the patentees. The owners of these patents were given assurances that the Government would ultimately meet proper and just claims for the use of these patents.

The plan adopted and the work done during the past three years by the Departments of War, Justice, and Navy jointly reveals a most commendable and businesslike method of avoiding useless and expensive litigation and at the same time securing, on a very low basis to the Government, an adjustment of claims aggregating many millions of dollars.

The painstaking methods pursued in this instance by the

joint action of three Cabinet officers under the former administration and consummated and approved by the Secretary of War, the Attorney General, and Secretary of the Navy under the present administration furnish ample argument for the passage of this bill.

In the fall of 1918 the War and Navy Departments found themselves confronted with a large number of accrued and rapidly accumulating claims arising out of the necessary use by the Government of practically all the modern radio telegraphic and telephonic appliances without regard to the rights of patentees.

A large number of manufacturers were virtually ordered by the Government to furnish appliances which clearly infringed the patent rights of others, and at the same time gave assurance that the Government would assume and, at the close of the war, discharge such obligations as arose out of such infringements.

Foreseeing the intricate and expensive burden that would be imposed upon the Government if the various conflicting claims of various patentees on various instrumentalities were allowed to accumulate through a period of years, the Secretary of War, the Attorney General, and the Secretary of the Navy in the fall of 1918 appointed the "inter-departmental radio board" composed of the ablest experts in their respective departments to make a thorough investigation of all such claims then pending and likely to arise against the Government, and also to determine the relative rights of various patentees toward each other, with relation to patents on certain specific inventions, and furthermore to determine the comparative value of each patented instrument in cases where their simultaneous and joint use by the Government was found necessary. The creation of this board was also more formally verified by the precept of the three Cabinet officers on February 12, 1921. This board for more than two full years assiduously devoted itself to hearings and investigations and succeeded in reducing the claims aggregating approximately \$30,000,000 to a settlement basis of \$2,500,000, and beyond this all the principals to whom it finds the Government under legal obligation, have been induced to settle on this reduced basis if payment can be effected without delay.

The practical value to the Government of the plan adopted has been so pronounced that the British Government, after

studying it, has adopted it for settlement of claims of similar and other character.

During the progress of the investigation it developed that there are approximately 2,500 United States patents in this art, all of which were living during the period covered by the board. All of these have had to be considered in one way or another; if not directly as patents under which claims are made, then as to their bearing on patents under which claims were made. In addition, hundreds of foreign patents and hundreds of United States and foreign publications have been sought out and considered in relation to their effect on those patents presented in the claims.

The claimants did not know precisely just what the Government had used, and many of them brought claims under all patents, with the result that the board had to laboriously proceed through several hundred patents, pick out those under which it was evident there was no infringement; and then by hearings with claimants, long drawn out, eliminate the chaff.

The board finally came down to a real serious consideration of 149 patents. This consideration involved searches [fol. 2339] of the art, writing of long reports, receipt of briefs from claimants, hearings, more briefs, revised reports, and then an accounting on those patents considered good, which were 27 in number, with much discussion following as to the methods of accounting and the effect of decisions thereon.

Such a task has been stupendous, and has required a force of experts—expert to begin with, but which became more expert daily in its specific task as it gained knowledge from experience.

Consider the chaos that would have existed if such a task (the serious consideration of 149 patents of a difficult art) had been presented to a number of courts in different places and at different times; for a single patent could be the cause of half a dozen suits in order to reach the numerous contractors for the Government; and then, after the patents had been sustained, the long drawn out procedure of accounting in each case, each accounting duplicating in many respects accountings in other jurisdictions.

Under our judicial system, and with the extreme difficulty in presenting patent cases, it is probable that the task could not have been covered in the courts in 25 years in the same comprehensive but centralized method of the board.

The Secretary of War, the Attorney General, and the Secretary of the Navy urge these settlements without delay and request the necessary legislation.

[fol. 2840] PLAINTIFF'S EXHIBIT 364

UNITED STATES DISTRICT COURT, WESTERN DISTRICT OF WASHINGTON, NORTHERN DIVISION

No. 71. In Equity

MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA,  
Plaintiff,

vs.

KILBOURNE & CLARK MANUFACTURING COMPANY, Defendant

On Lodge Patent No. 609,154 and Marconi Patent  
No. 763,772

FINAL JUDGMENT

At a Regular Term of the United States District Court for the Western District of Washington, Northern Division, held in the Federal Building, in the City of Seattle, on the 16 day of July, 1917.

Honorable Jeremiah Neterer, United States District Judge,  
Presiding

This cause came on to be further heard at this term and was argued by counsel:

And thereupon, upon consideration thereof, it was Ordered, Adjudged and Decreed as follows:

1. That letters patent of the United States issued to Oliver J. Lodge on the 16th day of August, 1898, No. 609,154, during the term thereof, were good and valid in law, as to claims 1, 2 and 5 thereof.

2. That the plaintiff, Marconi Wireless Telegraph Company of America, was the sole and exclusive owner of said Letters Patent No. 609,154 during the term thereof.

3. That the said Oliver J. Lodge was the first, true, original and sole inventor of the inventions described in said [fol. 2841] letters patent and claimed in said claims 1, 2 and 5.

4. That the defendant, Kilbourne & Clark Manufacturing Company, during the term of said Letters Patent, and before its expiration, infringed upon said claims 1, 2 and 5 of said Letters Patent, by manufacturing and selling apparatus containing, embodying or employing the inventions of said claims 1, 2 and 5 of said Letters Patent No. 609,154, or material or substantial parts thereof

5. That the defendant has paid the plaintiff the sum of Four Thousand Dollars (\$4000.00) in full of all claims for damages, gains and profits by reason of the aforesaid infringement of said claims 1, 2 and 5 of said Lodge Patent, including all claims against defendant's customers therefor, but exclusive of claims against the United States of America for apparatus infringing the said Lodge Patent manufactured or sold by the defendant herein for or to the United States of America, as per stipulation of the parties on file herein.

6. That the said patent having expired pending suit, no injunction shall issue restraining the said infringement.

7. That said Letters Patent of the United States issued to Guglielmo Marconi on June 28, 1904, No. 763,772, for apparatus for wireless telegraphy, are good and valid in law as to claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 16, 17, 18, 19 and 20, when properly construed in connection with the apparatus described in the specification of said patent, as more fully appears in the opinion herein filed.

8. That the plaintiff, Marconi Wireless Telegraph Company of America, is the sole and exclusive owner of said [fol. 2842] Letters Patent No. 763,772.

9. That the said Guglielmo Marconi was the first, true, original and sole inventor of the inventions described in said Letters Patent and claimed in the said claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 16, 17, 18, 19 and 20 thereof.

10. The manufacture and sale by the defendant of of its wireless apparatus known as the "Thompson Transmitter", the "Simpson Transmitter", and its Standard Receiver, or

either of them, as set forth, shown and described in the proofs herein, does not infringe upon the inventions described in said Letters Patent No. 763,772, and claimed in said claims 1, 2, 3, 6, 8, 10, 11, 12, 13, 14, 16, 17, 18, 19 and 20 thereof, or any of them.

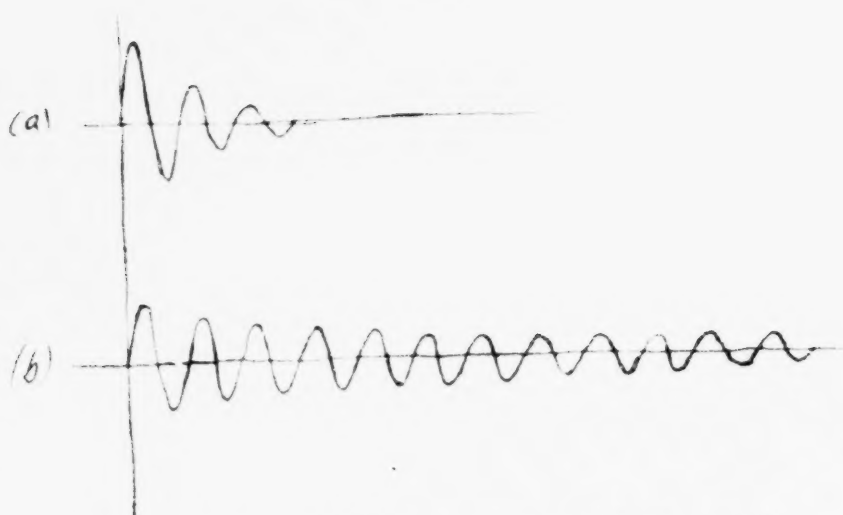
11. In view of the Act approved June 25, 1910, entitled "An Act to Provide Additional Protection for Owners of Patents of the United States and for Other Purposes", the Court has no jurisdiction to grant the prayer of the bill for an injunction and an accounting in respect to the wireless telegraph apparatus manufactured and sold by the defendant to the United States Government, a set of which was installed on the Steamship "Achilles", and the Court, therefore, makes no finding upon the question of whether said apparatus infringes the patent in issue.

12. That the prayer of the bill, so far as it seeks an injunction and an accounting in respect to defendant's said wireless telegraph apparatus installed on the Steamship "Achilles" as an infringement of each of the aforesaid claims of the said Lodge Patent No. 609,154 and Marconi [fols. 2843-2844] Patent No. 763,772, and so far as it relates to an injunction and an accounting in respect to the defendant's aforesaid "Thompson Transmitter", "Simpson Transmitter" and its Standard Receiver as infringements of each of the aforesaid claims of Marconi Patent No. 763,772, be and hereby is denied, and the bill of complaint, so far as it relates to such apparatus as infringements of said claims be and hereby is dismissed.

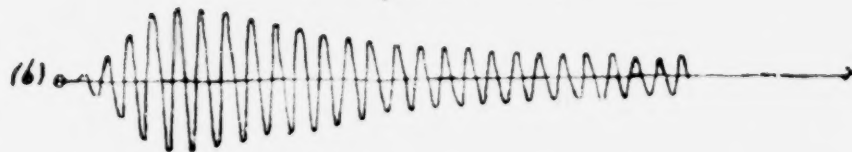
14. That no costs or disbursements heretofore incurred by either plaintiff or defendant in this proceeding be allowed or taxed in favor of either party hereto.

To paragraphs No. 10, 11, and 12 hereof, and each thereof, the plaintiff excepts, and said exceptions are hereby allowed.

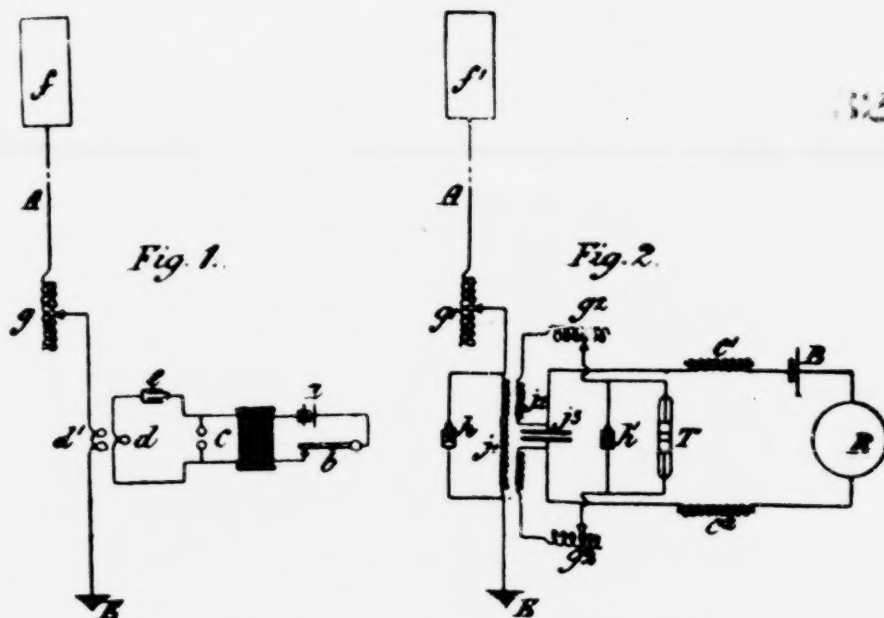
Jeremiah Netterer, United States District Judge.



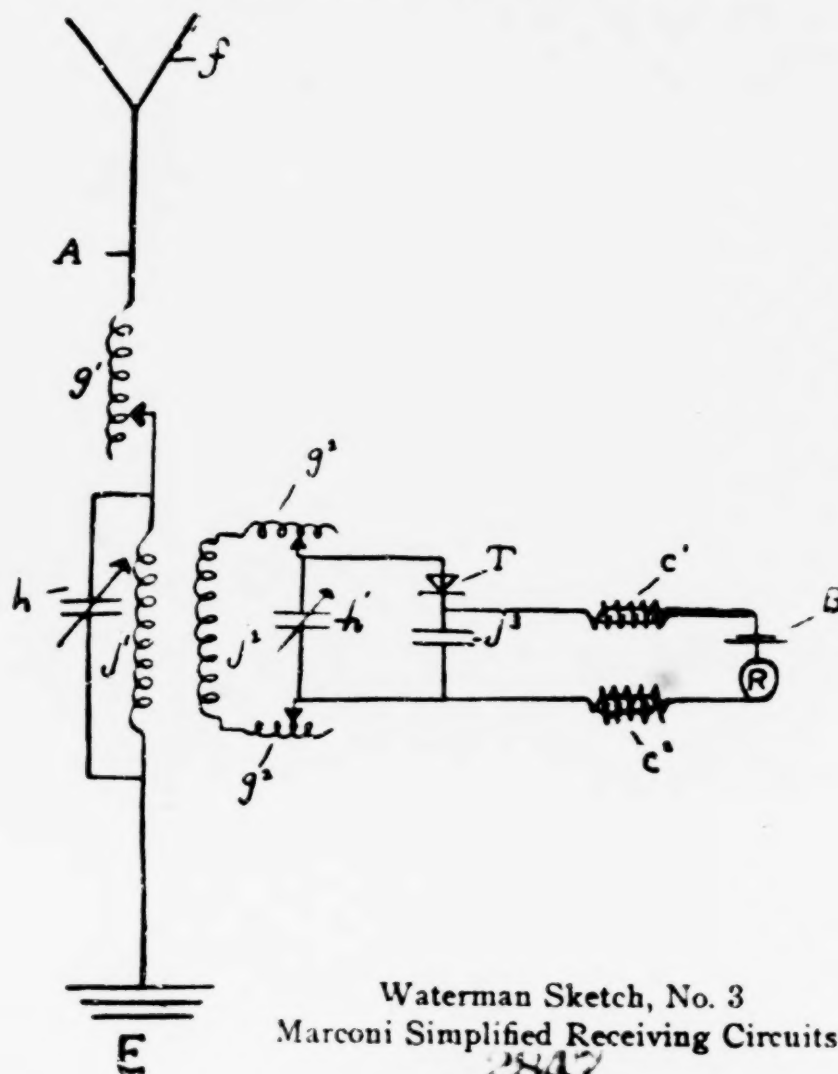
Waterman Sketch, No. 1—Effect of Lodge Coil

*Oscillations of Primary Circuit**Oscillations of Secondary Circuit*

Waterman Sketch, No. 2



Four Circuits or Tuning—Marconi Patent



2848

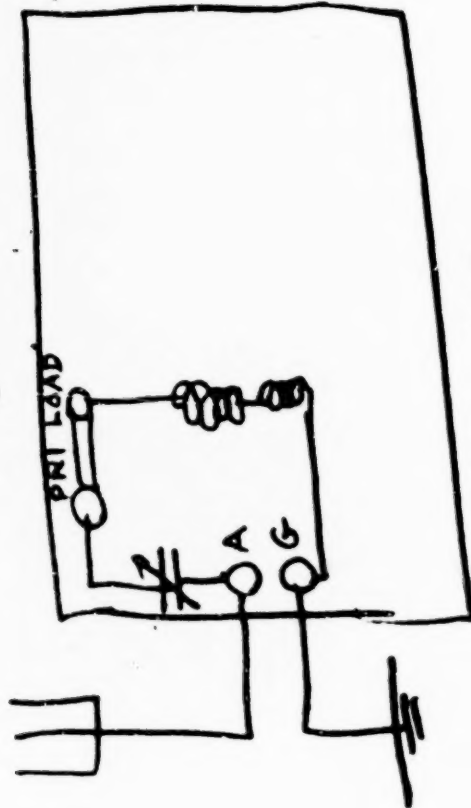
**FILED**  
MAY 14 1938  
**COUNT OF CLAIMS**

RE 410  
Apr 1938

3260

Plaintiff's Ex. 410

Fig. 1a



Series

Fig. 2a

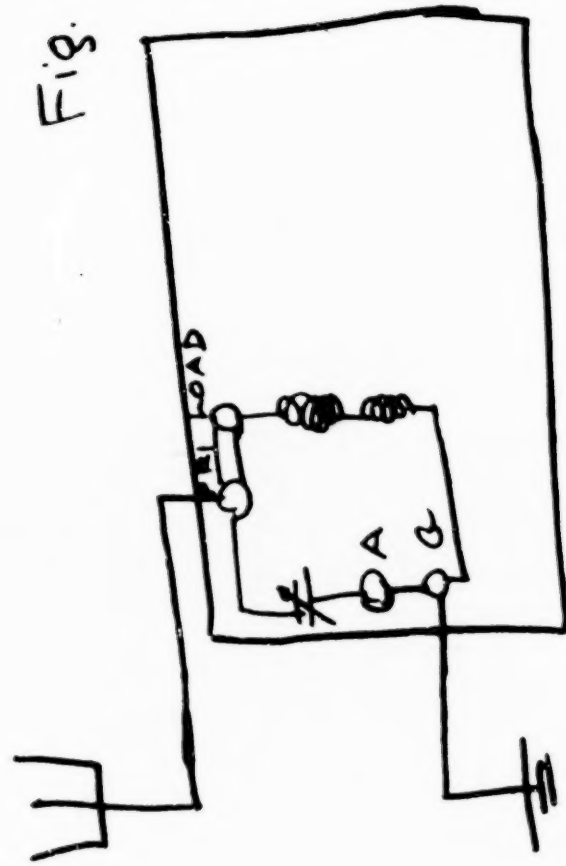
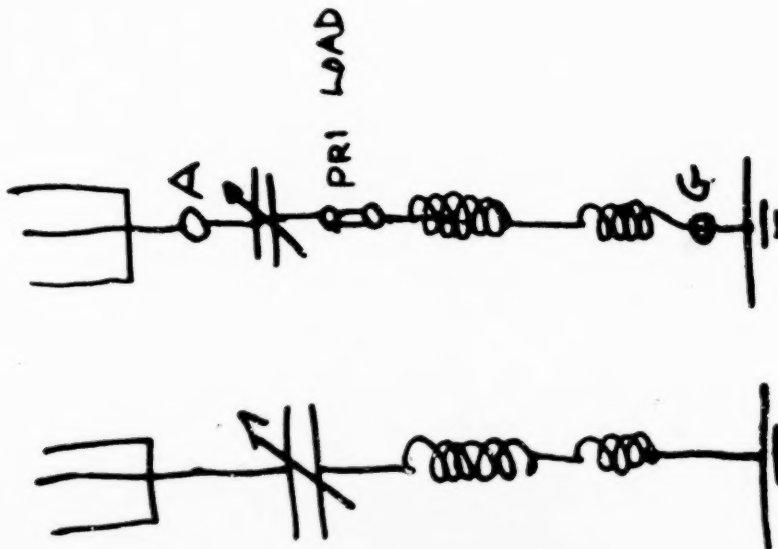


Fig. 1 Fig. 2



**FILED**  
MAY 14 1938  
COUNT OF CLAIMS

SE143

P-413A

U.S. NAVY RADIO RECEIVER

TYPE SE 143

Range 250 to 3100 meters

DESCRIPTION AND OPERATING  
INSTRUCTIONS

RADIO TEST SHOP  
U. S. NAVY YARD  
WASHINGTON, D.C.  
May, 1918

Approved:

W. A. Eaton,  
Lieut. (j.g.) U.S.N.  
Radio Officer.

## DESCRIPTION AND DIRECTIONS FOR THE USE OF U.S. NAVY

## SHORT WAVE RECEIVER

## TYPE SE 143

This instrument is designed primarily for the reception of spark signals; secondarily for the reception of long, sustained waves, using an audion control box as a detector. A four pole, double throw switch in the receiver permits of the use of either crystal detector or audion, both of which may be permanently connected to the receiver.

The range of the primary of this receiver is 250 to 3100 meters. The range of the tuned secondary is 250 to 6800 meters. The primary may be increased from its normal range of 3100 meters to over 7000 meters on any antenna by connecting as shown in Fig. 1.

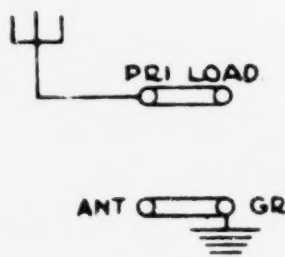


Fig. 1.

This places the primary variable condenser in parallel with the primary inductance. This combination is very efficient on waves longer than 3000 meters; on short waves, it is not as efficient as the series capacity.

The change over from shunt to series connection can be made quickly by using a double pole double throw switch as shown in Fig. 2.

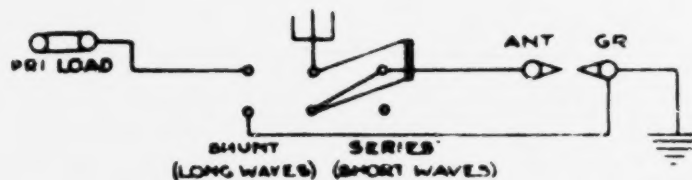


Fig. 2.

The receiver circuit, with detector switch on "AUDION", is shown schematically in Fig. 3.

## DETAILED SPECIFICATIONS

## ANTENNA CIRCUIT:

The antenna circuit of this receiver has a wave length range of 250 to 3100 meters when used with an antenna of 0.0008 mf. capacity. A greater range may be obtained by connecting the primary condenser in parallel with the primary inductance as previously described. The antenna circuit consists of a large, air dielectric, variable condenser, minimum capacity about 0.00008 mf. and maximum capacity 0.0045 mf.; a primary cylindrical loading coil, a primary coupling coil, inductance switches and coil cutouts.

The cylindrical loading coil consists of a micarta tube 5 inches outside diameter and 6.625 inches long, wound with a double bank winding of 212 turns of 3x16x38 Belden Litzendraht, and has an inductance of 3.8 millihenries.

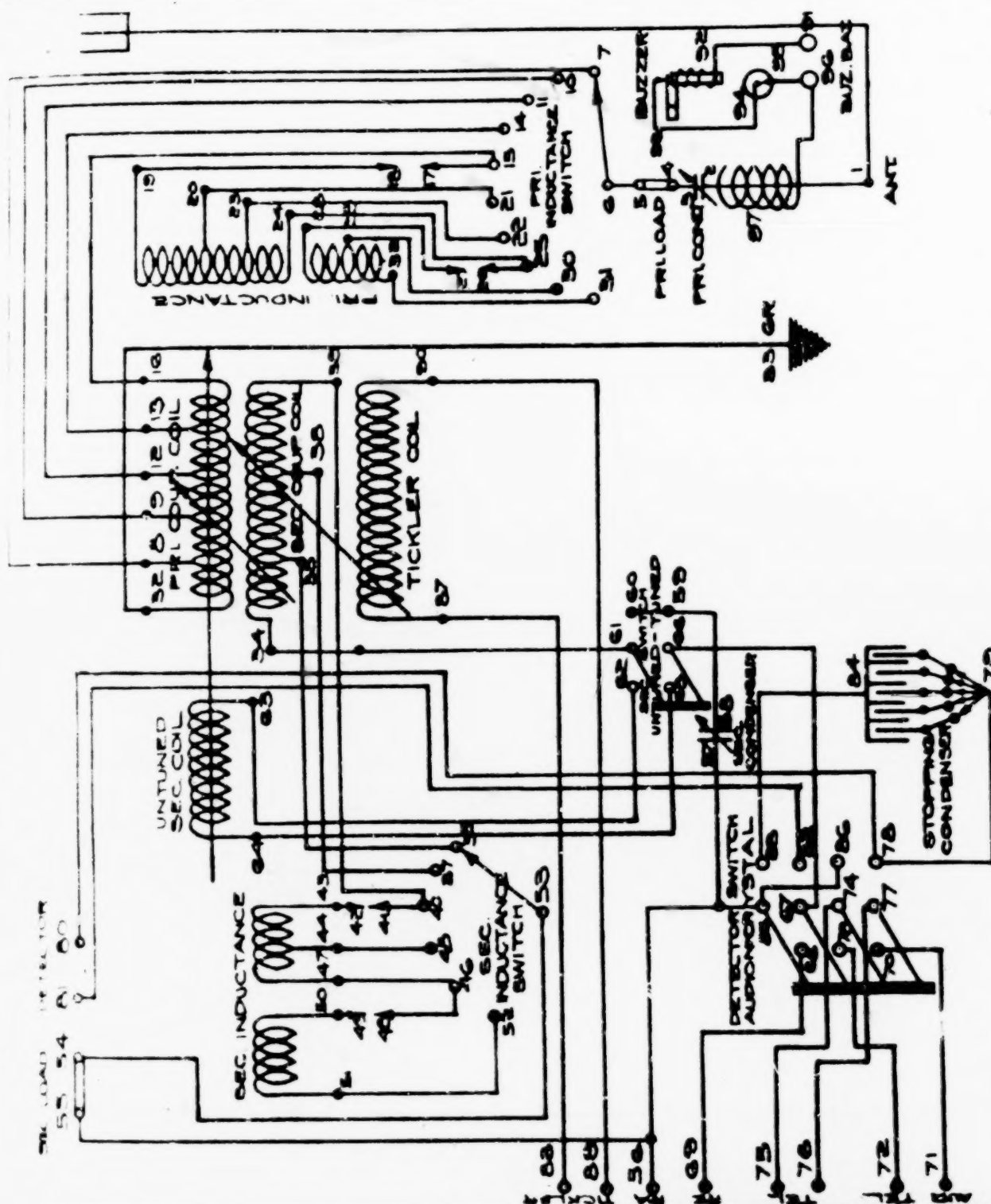
The primary coupling coil is 5 inches in outside diameter, 2 inches long, wound with a double bank winding of 47 turns of 3x16x38 Belden Litzendraht, and has an inductance of 0.42 millihenries.

The primary loading coil is wound in two sections; an air gap of 5/16 inch separating the first 94 turns from the remaining 118. This sectionalizing scheme is adopted to cut down both the distributed capacity and the natural period of the coil.

The primary condenser is of the balanced plate type. The fixed and movable plate systems are in two sections arranged 180 degrees from each other to balance the movable plate system mechanically. A knob marked FINE ADJUSTMENT is mounted on the receiver panel to the left and below the handle of the variable condenser. This knob permits of fine adjustment of the primary condenser through gears connected to the movable plates. A small sector, of 7 degrees, is cut from each end of the movable plates of the condenser. A sector, of 10 degrees, is cut from each end of the fixed plates of the condenser. This increases the ratio of maximum to minimum wave length of each coil, by reducing the end plate capacity to a minimum. The movable plate system carries a German silver dial on which the antenna wave lengths may be marked either in pencil or in India ink. An external loading coil may be inserted into the antenna circuit by connecting to the binding posts marked PRI. LOAD. COIL after removing the short circuiting link.

## SECONDARY CIRCUIT:

The secondary circuit has a wave length range of from 250 to 6800 meters. There is an overlap of at least 35 per cent. on each of the steps of secondary coil.



ALTERATION TABLE			CALL SIGN	POSITION
REMARKS	DATE	INITIAL	TRACER	MAP
			TRACER	
			CHANGE OF POS. LOCATION	TIME DATE
			APPROVAL	
			EXPERT RADIO AIDS	
			RADIO OFFICER	

MACHINERY DIVISION  
U. S. NAVY YARD NEW YORK N.Y.  
RADIO TELEGRAPH

# SHORT WAVE RECEIVER TYPE SE 143 WIRING DIAGRAM

SCALE — DATE 12/27/18

S E 950

ANALYSIS OF SWITCHING FOR SE SERIES-SHUNT CONNECTIONS OF PRIMARY CONDENSER

Fig. 1

Cam as on  
Sheet 8 of  
Px.416-A.  
Switch arm  
on contact A

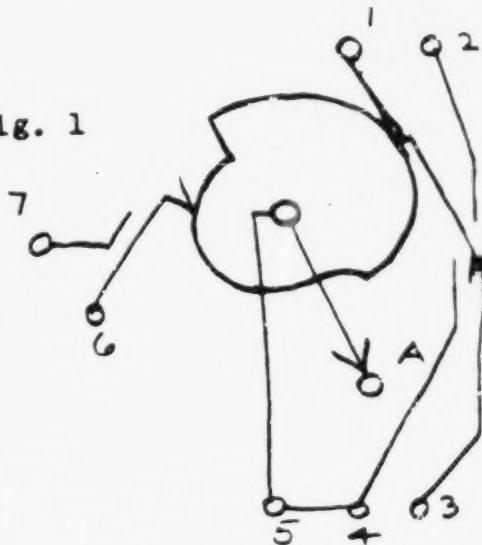
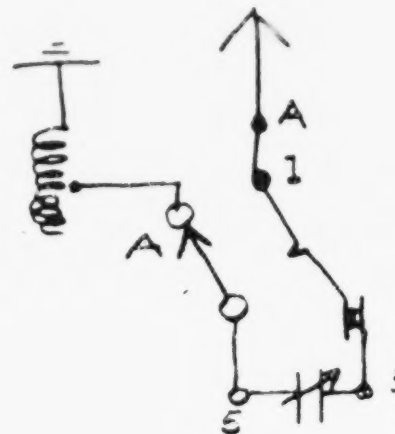


Fig. 2 1A  
Schematic drawing  
of series connection.



Cam in extreme opposite  
position of that shown  
in PX 416-A.  
Switch arm on contact 2 & 3

Fig. 2

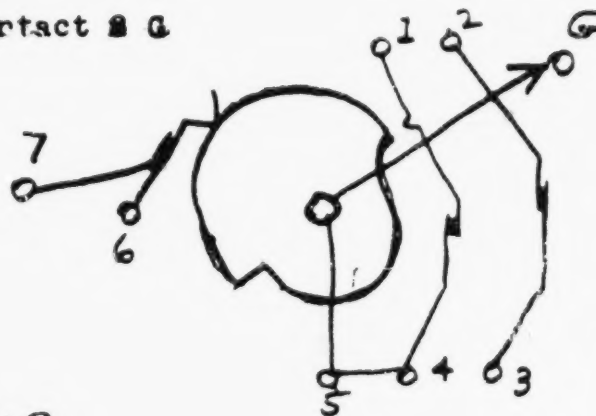
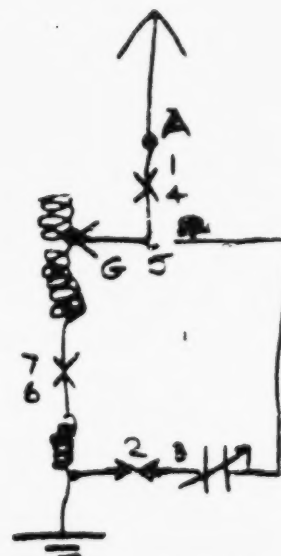


Fig. 2A



Schematic drawing  
of shunt connection

Pltff's Ex. 419  
at 4/20/38

Old 420  
at at 20/38

S E 1012  
ANALYSIS OF SWITCHING FOR SERIES-SHUNT CONNECTION OF PRI. CONDENSER

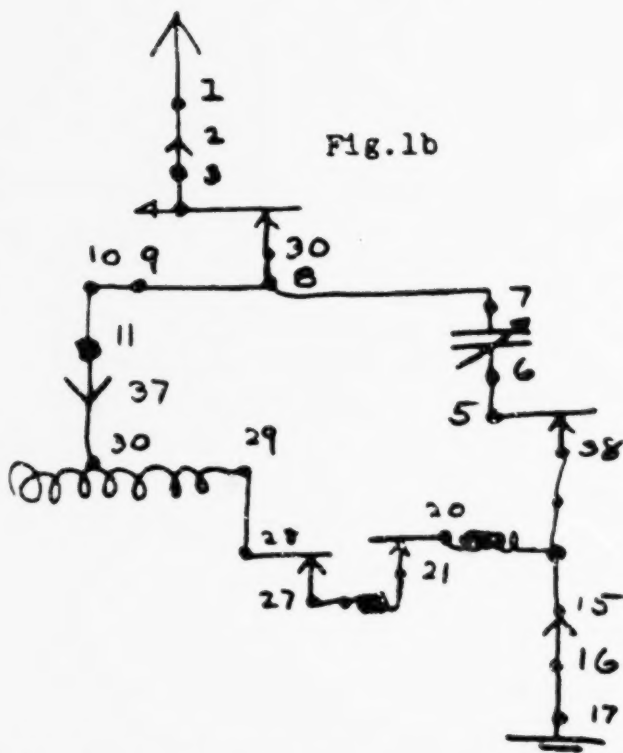
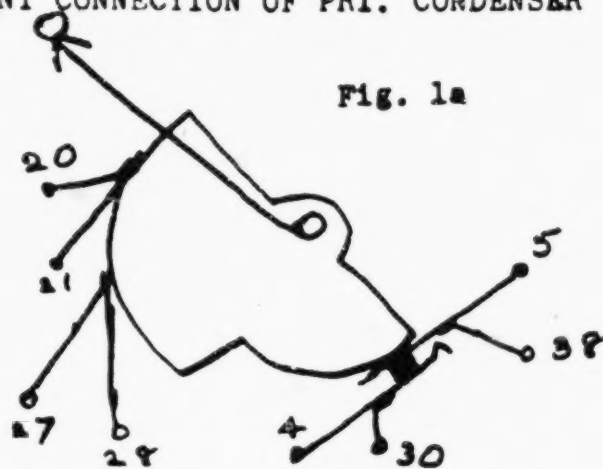
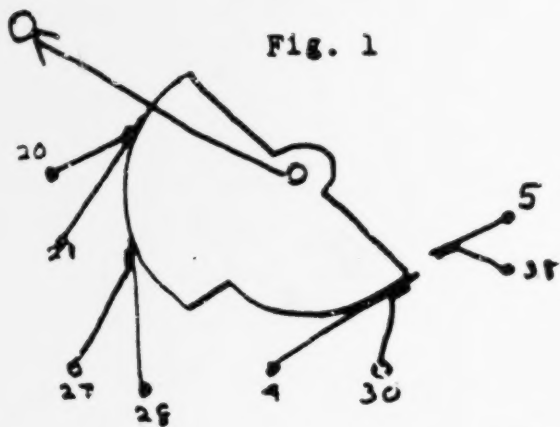


Fig. 2a

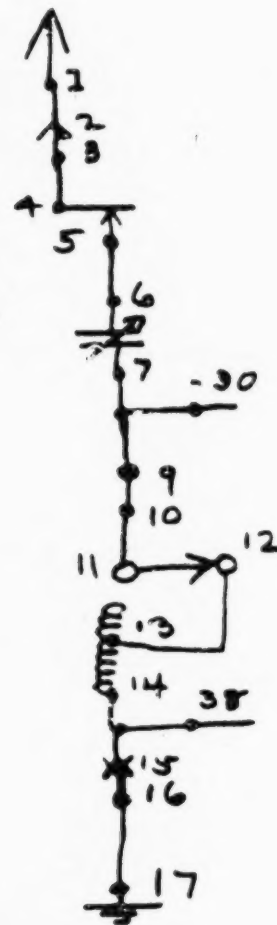
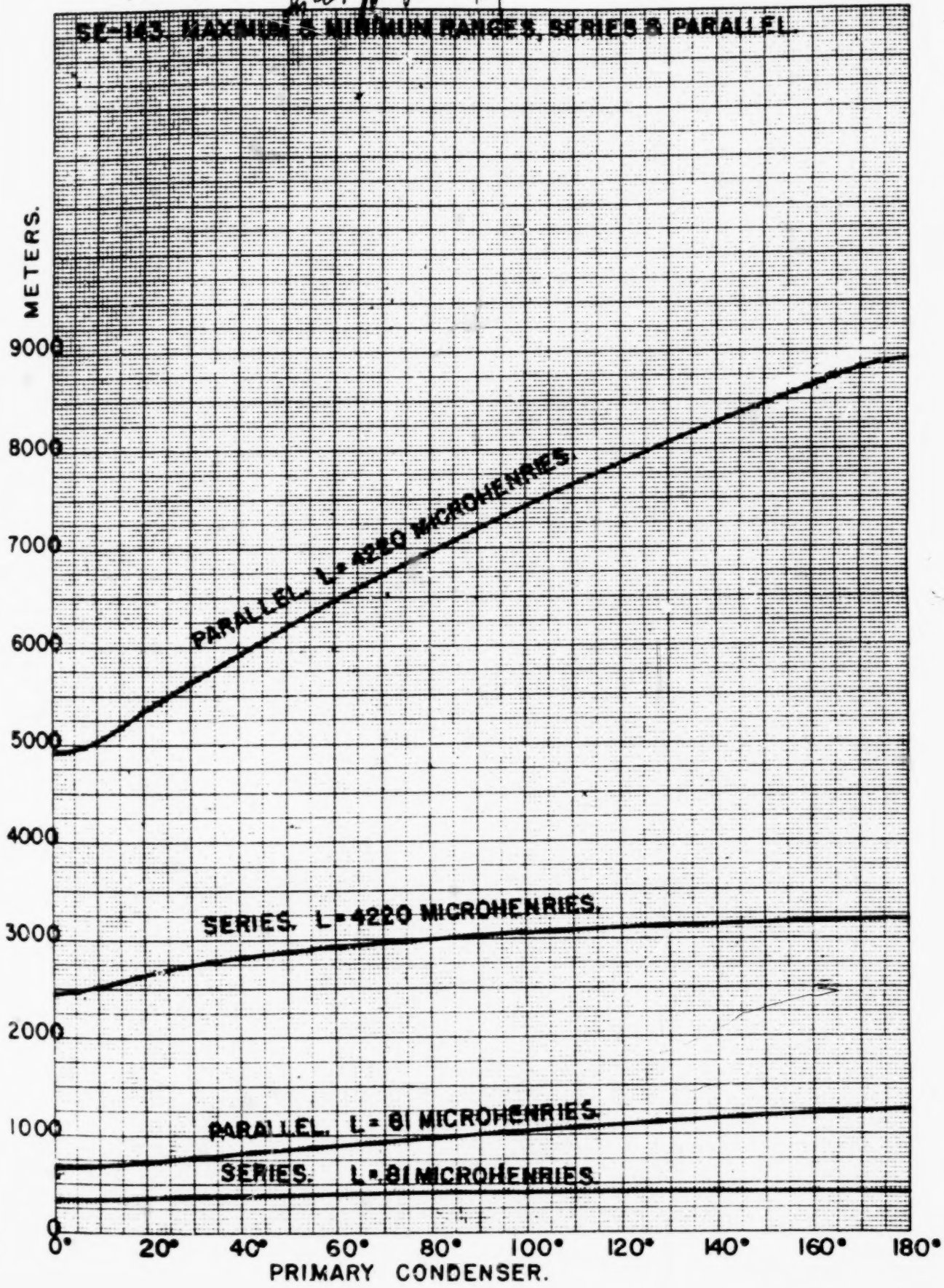


Fig.1. Cam switches as shown in PX 417. Inoperative.  
Fig.1a. Cams shown correctly; long wave (shunt) position.  
Fig.2 Cams shown correctly; short wave (series) position.  
Fig.1b Circuit for shunt operation.  
Fig.2a Circuit for series operation.

4-19-38  
GHC

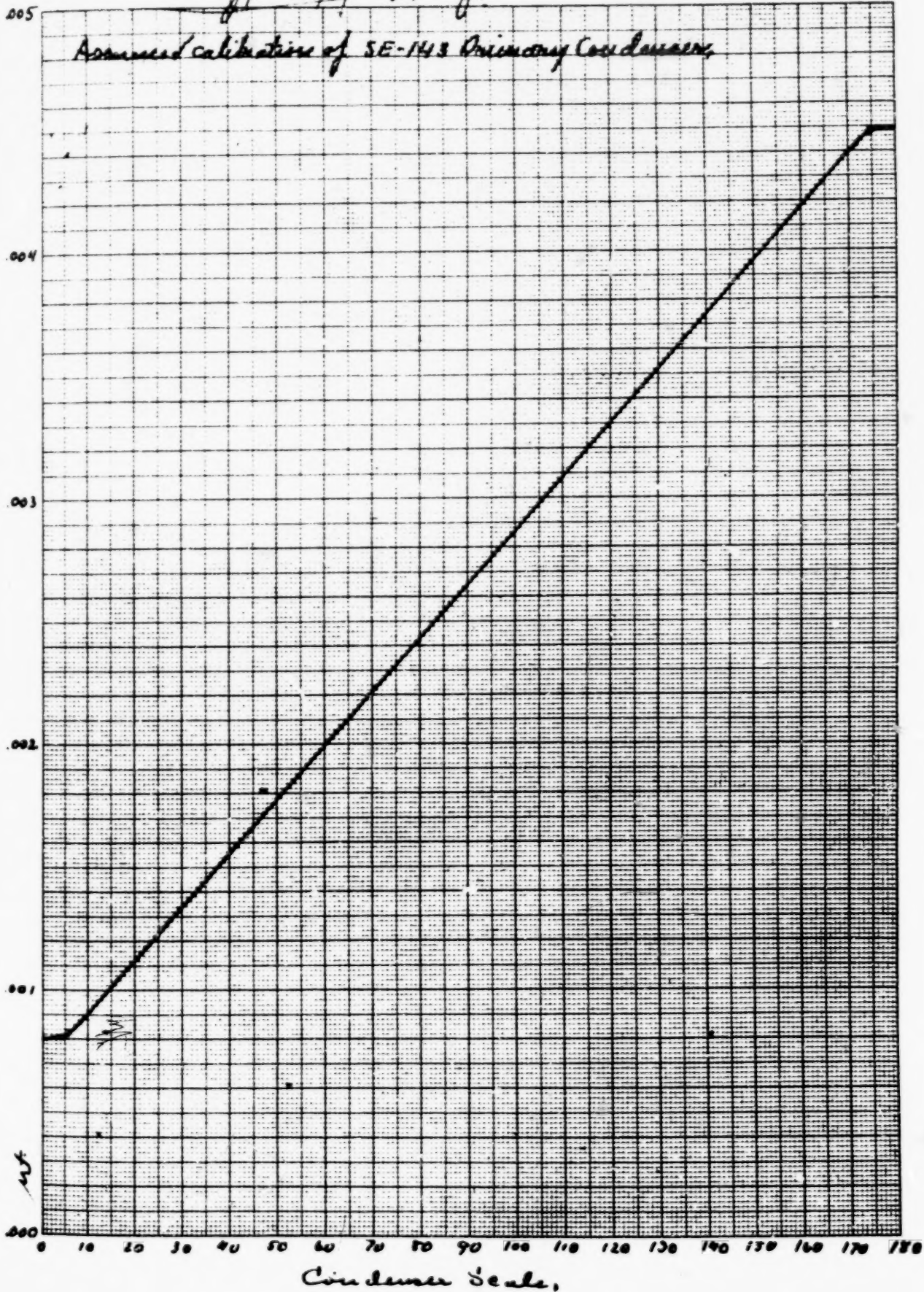
Plaintiff's Ex 440  
 In A. N. J. 3/1/39

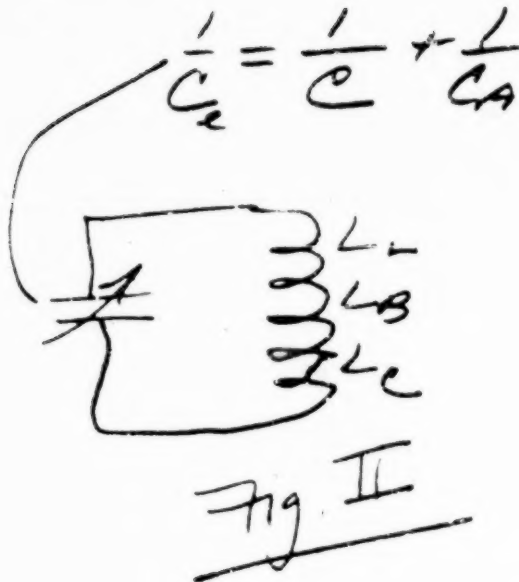
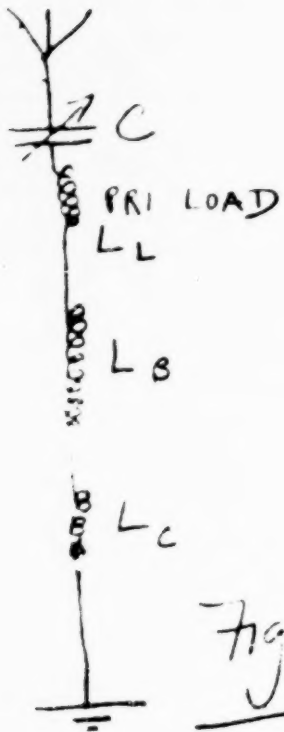
Plaintiff's Exhibit 440



Plaintiff's Ex 441 ~~Sheet~~  
 for 3/21/39 Dr. E. J. R.

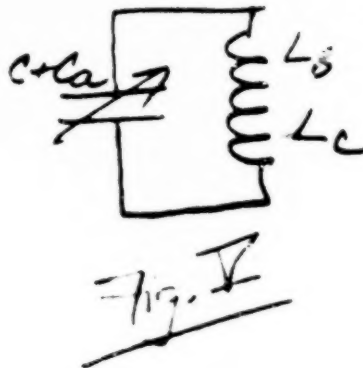
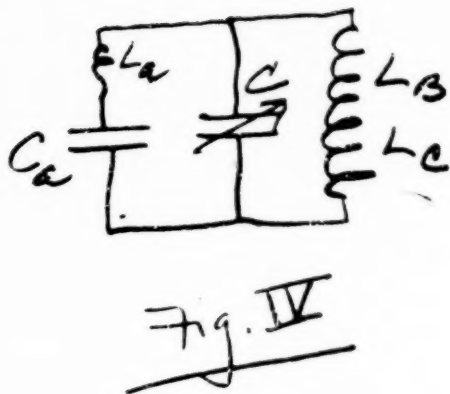
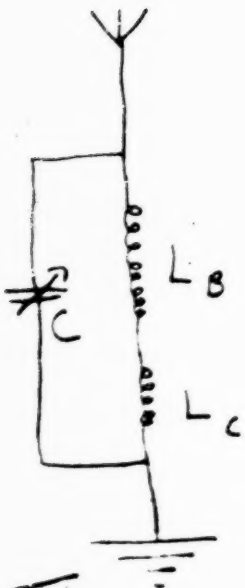
Plaintiff's Exhibit 441





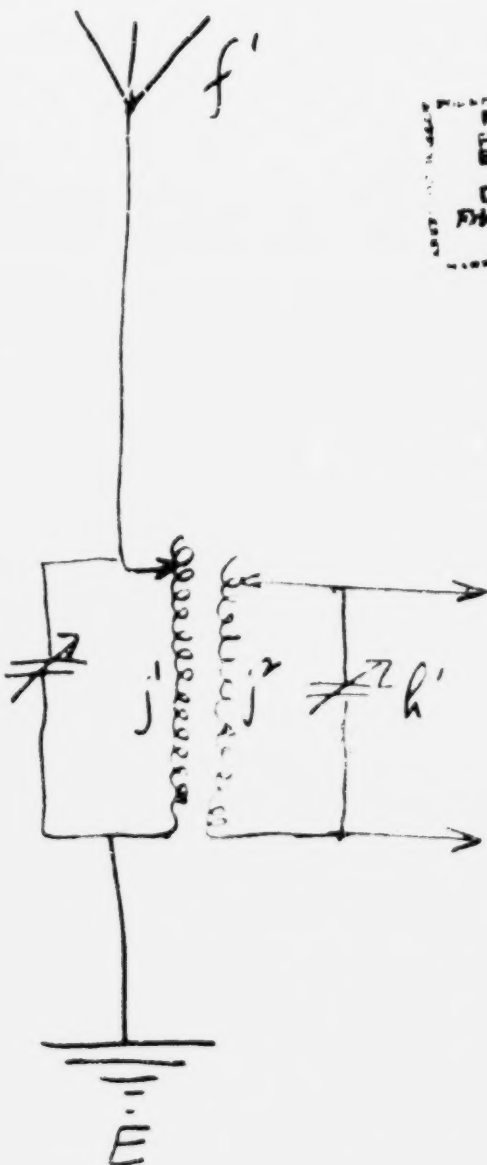
RECEIVED  
FEDERAL BUREAU OF INVESTIGATION  
JAN 19 1934  
U.S. DEPARTMENT OF JUSTICE  
WASHINGTON, D.C.

EXHIBIT 453  
DATE 1/19/34  
J. H. L. C. B. R.  
LAW REPORTER



3270

Pltff's Ex. 454



FOR IDENTIFICATION  
PLAINTIFF NO. 454  
DATE 2/18/39  
Edward W. Cooper, C. S. R.  
LAW REPORTER

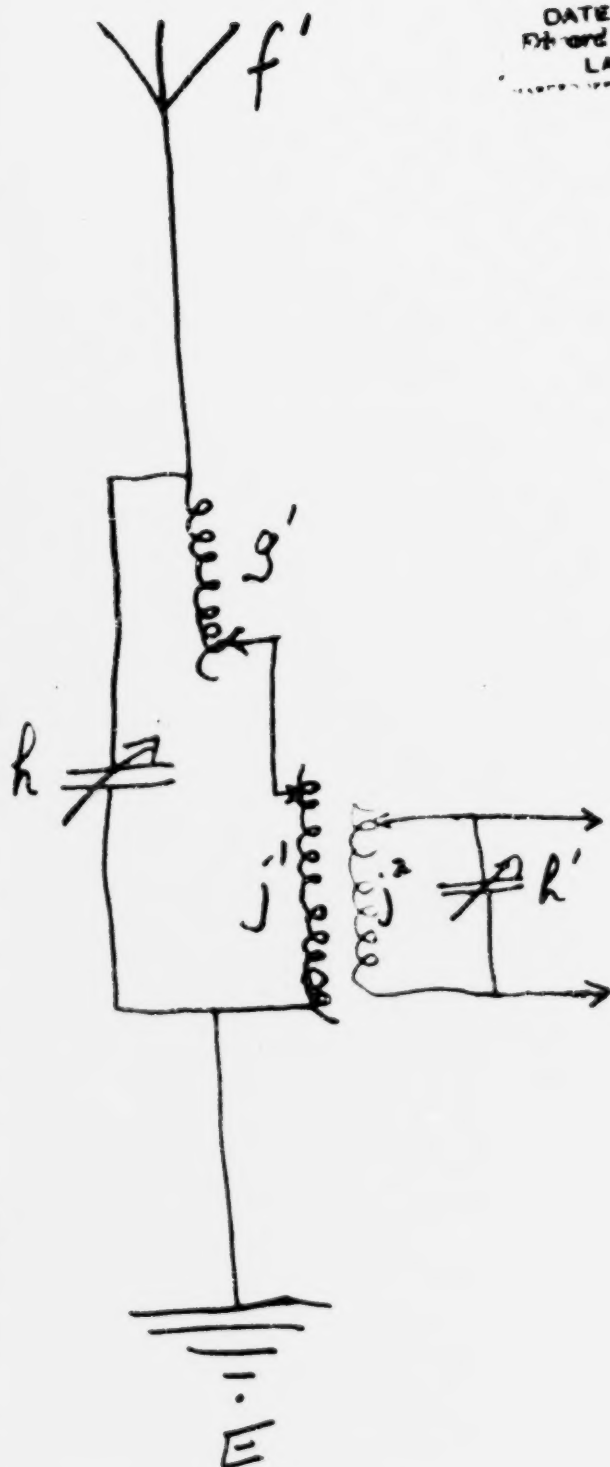
EXHIBIT  
PLAINTIFF NO. 454  
DATE 2/19/39  
Edward W. Cooper, C. S. R.  
LAW REPORTER

3271

Pltff's Ex. 55

EXHIBIT IDENTIFICATION  
 PLAINTIFF NO. 455  
 DATE 7/18/39  
 Edward W. Cooper, C. S. R.  
 LAW REPORTER

EXHIBIT  
 PLAINTIFF NO. 455  
 DATE 7/19/39  
 Edward W. Cooper, C. S. R.  
 LAW REPORTER



# Mark

Dec. 19 1912  
10:10 am wash. time

Transmits  
+ receive  
aerial

are signals.

(Put in new secondary coil  
with less resistance than  
old one; This sec. is #111-5)

$$C_1 = 120^\circ + 1 \text{ fx}$$

$$L_1 = 2 \text{ coil}$$

$$C_2 = 118^\circ + \frac{1}{2} \text{ fx}$$

$$L_2 = \text{coil I.}$$

$$C_{plg} = 1$$

$$\text{shunt} = 15^\circ \text{ Ticker } 150^\circ/\text{m}$$

$$C_1 = 82^\circ + 0$$

$$L_1 = 3 \text{ coil}$$

$$C_2 = 116^\circ + \frac{1}{2} \text{ fx}$$

$$L_2 = \text{coil I}$$

$$K = 1.3$$

\*  
→

$$\text{SS } \dots = 7^\circ \text{ Ticker } 150^\circ/\text{m}$$

Transmits  
+ receive  
aerial

$$L_2 = 2.6 \text{ mh}$$

$$L_1 = 3 \text{ coils}$$

$$C_1 = 124^\circ + 0$$

$$C_2 = 116^\circ + \frac{1}{2} \text{ fx}$$

$$\text{coil I}$$

$$50^\circ \pm$$

462  
462  
2

W3V

at Key West

17 1273

by VK-1

Dec. 20/ 1912.

1 p.m. - 3 p.m. Ticker out of adjustment - no wire available for contact. Rec'd some artful from Key West.

5 p.m. arc signals

$$L_1 = 3 \text{ coils } C_1 = 146^\circ + 0.6x$$

$$L_2 = \text{coil I } C_2 = 105^\circ + \frac{1}{2}x$$

$C_1$  parallel to  $L_1$

$$K = 1$$

shunt = 50 $\omega$  tickers 150 $\omega$  for

Dec. 21 1912.

First schedule rec'd, @ being on shore, was at 1.00 $\omega$  (890 miles)

1.00 P.m. arc.

$$L_1 = 3 \text{ coils } C_1(11) = 132^\circ + 0.6x$$

$$L_2 = \text{coil I } C_2 = 102^\circ + \frac{1}{2}x$$

$$K = 1.5$$

shunt = ~~40 $\omega$~~  Tickers 1.00 line.

compensation wave ~~and~~  
Re Setter U $\omega$  (890 miles)

1.00 P.m.

3 coils C

coil I C

$$K = 1.5$$

shunt = 30 $\omega$

had to cut out  
does to get  
to cut out

~~Antenna~~

PLAINTIFF'S EXHIBIT 472

**ROBISON'S MANUAL**  
OF  
**RADIO TELEGRAPHY**  
AND  
**TELEPHONY**

FOR THE USE OF  
**NAVAL ELECTRICIANS**

BY  
CAPTAIN S. S. ROBISON, U. S. NAVY

REVISED BY  
CAPTAIN D. W. TODD, U. S. NAVY  
Director Naval Communications

AND  
LIEUT. COMMANDER S. C. HOOPER, U. S. NAVY  
In Charge of Radio Division, Bureau of Steam Engineering

4TH REVISED EDITION

NEW YORK  
JOHN WILEY & SONS  
1918

Fig. 82 represents circuits of a receiving set complying with present specifications. In all such sets closed circuits are calibrated and curves drawn or a scale furnished showing wave lengths for all settings from 200

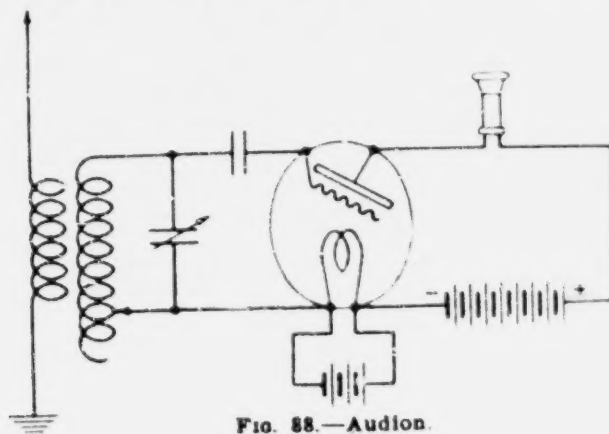


FIG. 88.—Audion.

to 4000 meters, and additional calibrated loading coils for very long waves are supplied.

With very loose coupling the wave length of received signals can thus be read directly.

300. Fig. 89 represents a receiving circuit for continuous oscillations: it shows the receiving telephone connected across the terminals of a fixed condenser in series with the detector.

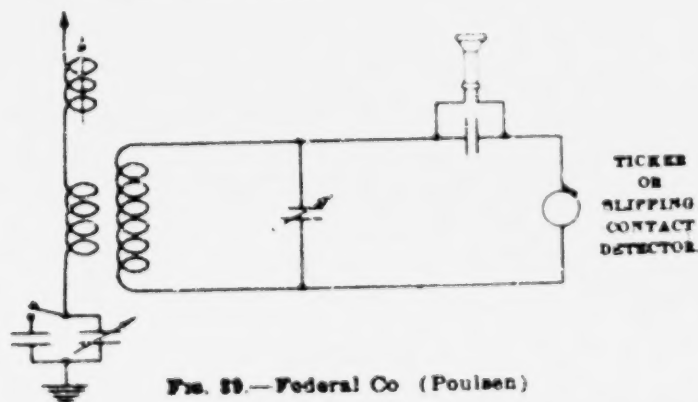


FIG. 89.—Federal Co. (Poulsen)

In using undamped oscillations for wireless telegraphic purposes it must be remembered that the frequency of the oscillations themselves is too high to be heard in the telephone connected with the ordinary receiving circuit, and when the circuit at the sending station is closed all that would be heard is a slight click, so that there is no way of telling a

as possible. With properly adjusted carbons, the instrument should operate an hour without attention and then requires only the careful cleaning and facing up of the carbons.

202. In spark sets we want the sending aerial to be a good radiator, but not so good that it will give a whip crack discharge. We want its oscillations to be persistent enough to require for their best reception a receiving aerial tuned to the period of the sender, and as a present standard we have set for the sender a damping considerably less than .2, so that it makes fifteen complete oscillations before the oscillating current falls to 1 of its original value. We want the receiving aerial to radiate as little

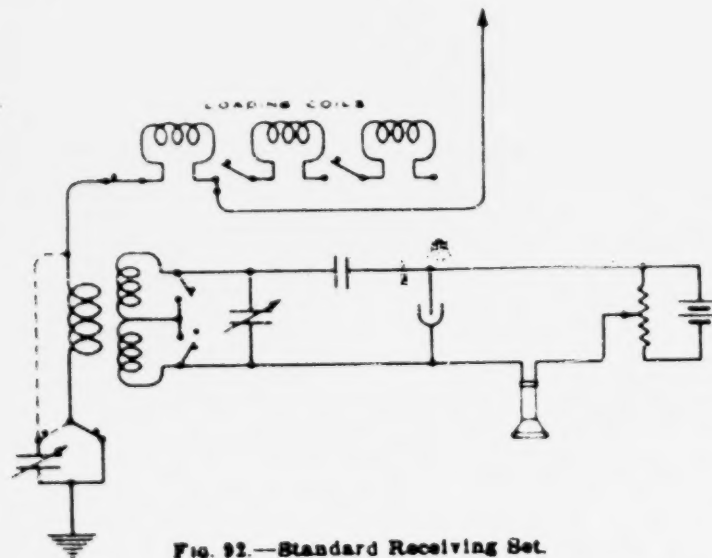


FIG. 92.—Standard Receiving Set.

as possible; but to so combine the energy of the fifteen waves that the highest maximum is produced in the aerial, and transferred to the closed receiving circuit.

If the sending aerial is coupled so as to send out waves of two lengths, there appears to be no question that the coupling of the receiving circuits should be such that, if they acted as senders, they would send out waves of these lengths, or so loosely coupled that their natural period is that of the arriving wave containing the most energy. If, in the case of very loosely coupled circuits or those supplied with quenched spark gaps, but one wave length is being radiated, receiving circuits should also be loosely coupled or should be coupled so that the transfer of energy from the open to the closed circuit and the damping of the latter (with the detector, however connected) is at such a rate that a maximum current in the closed circuit is reached at the instant the open circuit has come

*Acknowledgment.*

25. NQM ..... Station which sent message.  
 26. ● ■ ● ..... Received.  
 27. 5 ..... No. of message.  
 28. NAR ..... Receiving station  
 29. SF' ..... Receiving operator's sign  
 30. ■ ● ■ ..... Go ahead.

*Finished Signal.*

31. ● ● ● ■ ● ■ ..... Finished.  
 32. NQM ..... Sending station.

## RECEIVING.

249. In ordinary circumstances, while listening in, the set may be kept closely-coupled, to broaden the tune; but the aerial circuit should be stiff, i. e., having a considerable amount of inductance (art. 231). The aerial circuit should be tuned with a variable condenser in series for short waves and in parallel (around inductance) for long waves (fig. 92).

When the calling station is well tuned in, loosen the coupling, if there is interference. This should be done gradually, *adjusting both the open (aerial) and closed circuits with each change of coupling*, until a point is reached where signals are readable through the disturbances. With fairly strong signals the coupling on a 1 P. 76 receiver should be not less than 18 on the coupling scale, and, at this point, for moderate wave lengths, the signal should not fall materially in intensity.

For further improvements in tuning, the closed circuit condenser should be made as large as possible and the closed circuit inductance correspondingly reduced.

The settings (for best coupling and of open and closed circuits) for all stations habitually communicated with should be recorded and posted for the use of the operator on watch.

The practice of loosening coupling while receiving should be *made obligatory* on all operators. It not only cuts out existing interference, but prepares for any interference which may arise during reception. Owing to the change of effective self-induction, in both circuits, both require readjustment (retuning) with each change of coupling.

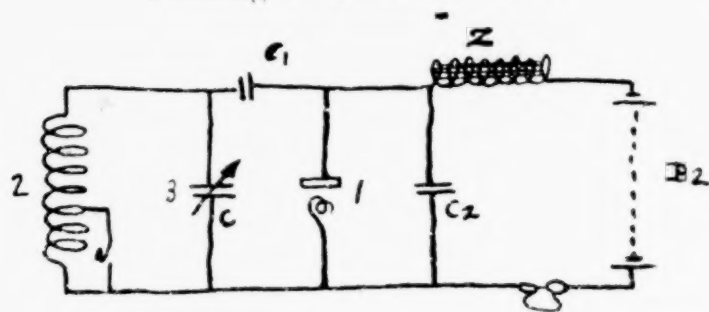
Two aerials in the same immediate vicinity as on board the same ship have an influence on each other so that if both are used for receiving at the same time, the tuning of either will affect the other and this effect may be observed between aerials on different ships if they are very close together.

250. When two ships are close together, the one which is not doing the sending can generally assist in receiving faint signals. Regardless of opening of circuits, high power sending lessens the sensitiveness of the

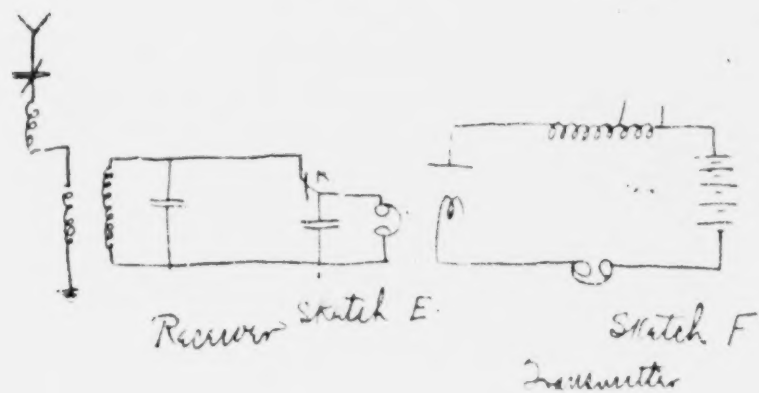
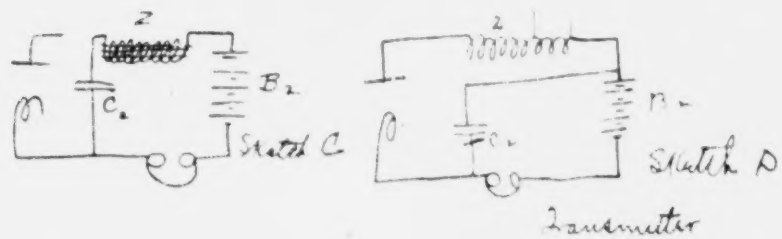
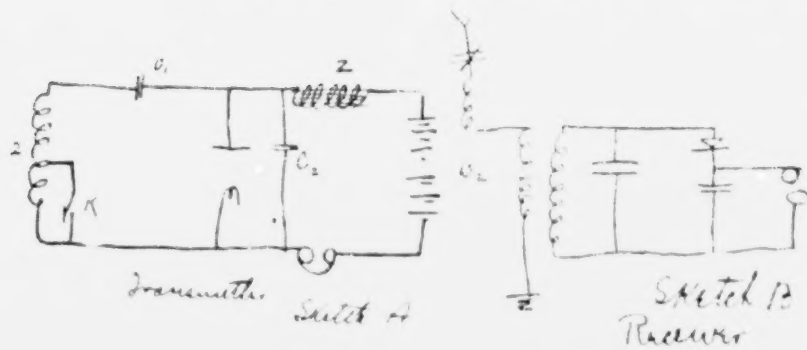
Defendant's Exhibit "A"



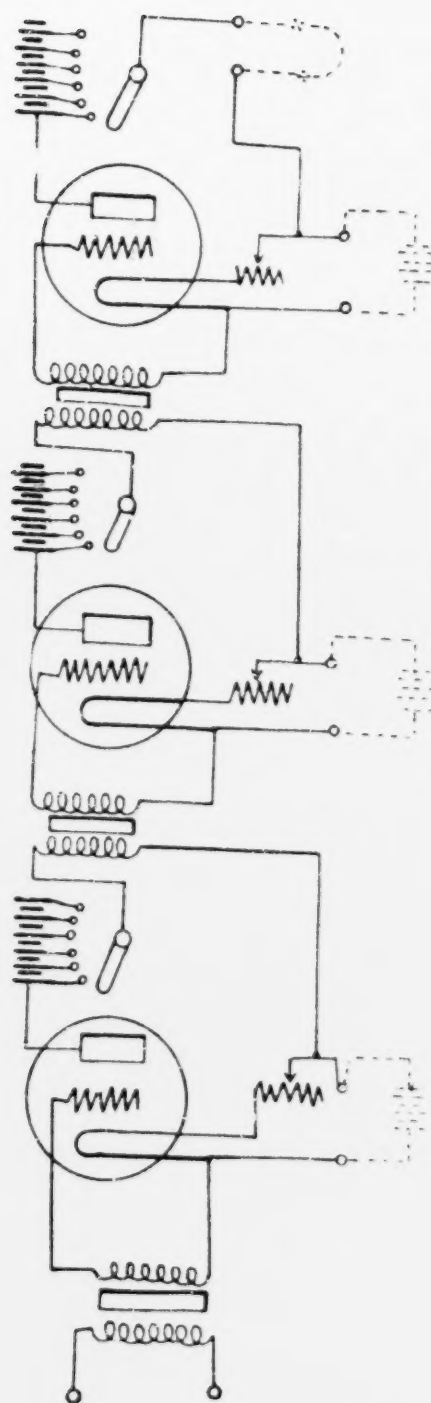
Defendant's Exhibit "B"  
Fleming Two-Element Valve



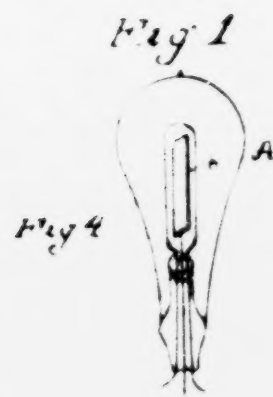
Defendant's Exhibit "C"



Defendant's Exhibit "D"



DEFENDANT'S EXHIBIT I  
*MILLER DRAWING A*



# MILLER DRAWING B

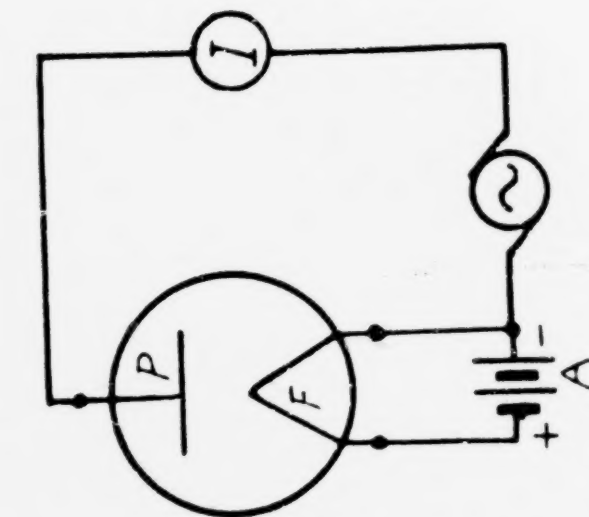


Fig. 1

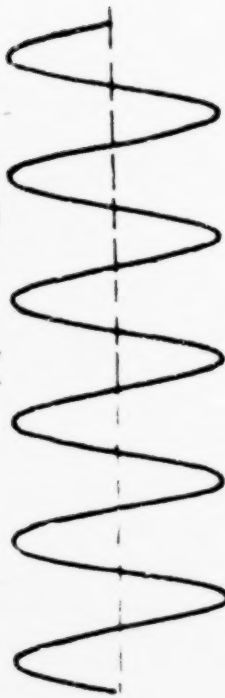
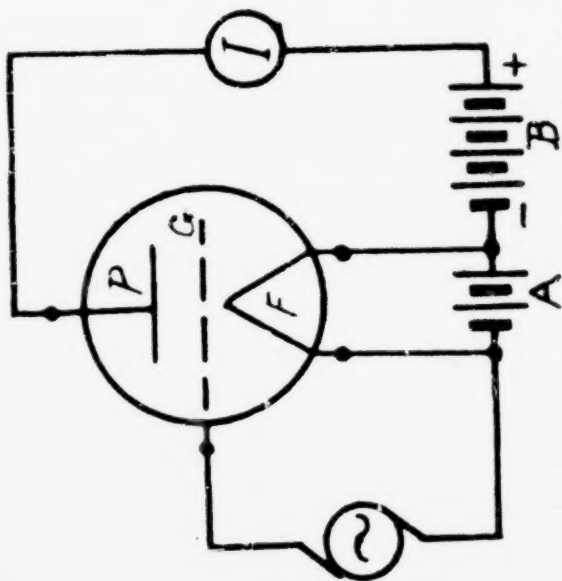


Fig. 2

MILLER DRAWING C

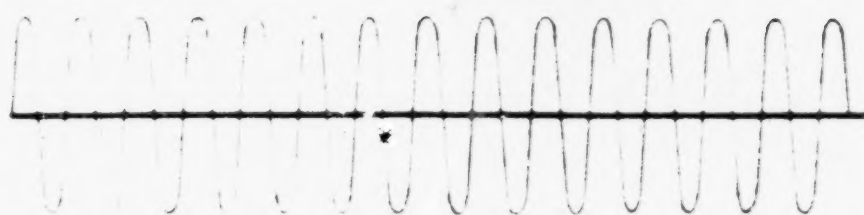


Fig. 1



Fig. 2

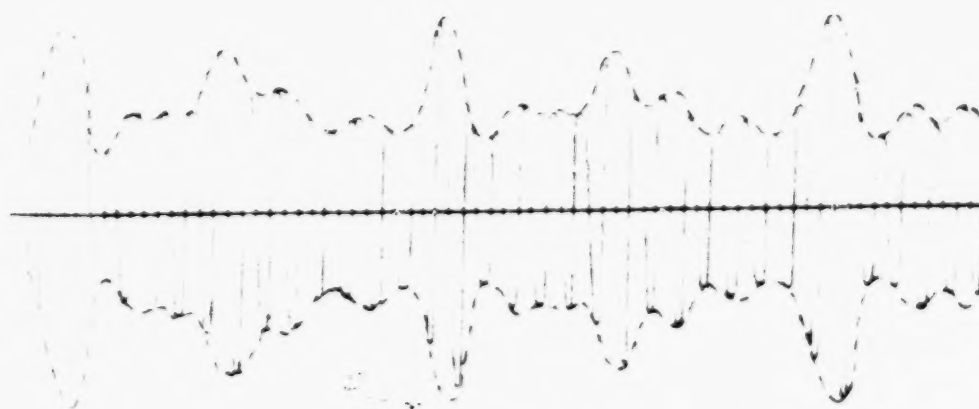


Fig. 3



Fig. 4

# MILLER DRAWING 1 D

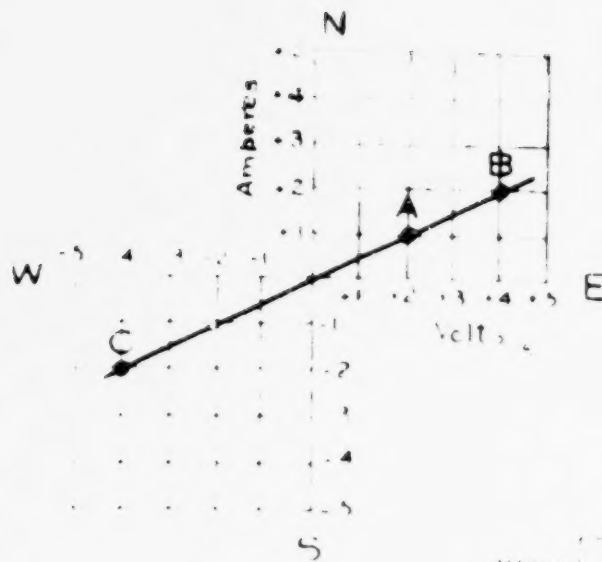


Fig. 1

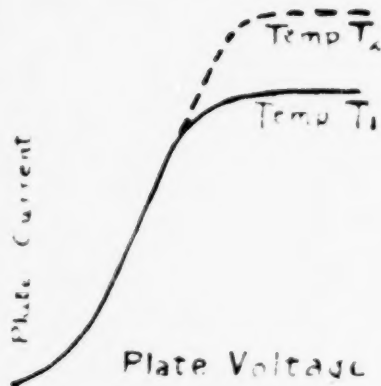


Fig. 3

Characteristic curves of a two electrode tube for two different Temperatures.

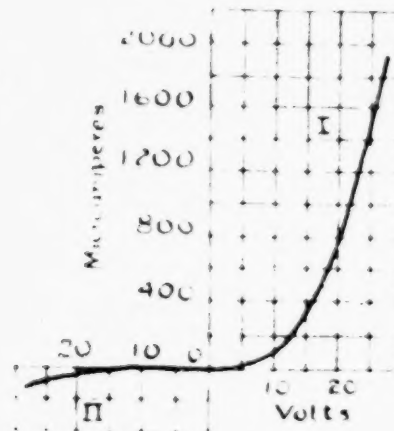


Fig. 2

Curve showing the interdependence of the conductance in direction better than the other



Current  
Fig. 4

Current voltage characteristic of the arc

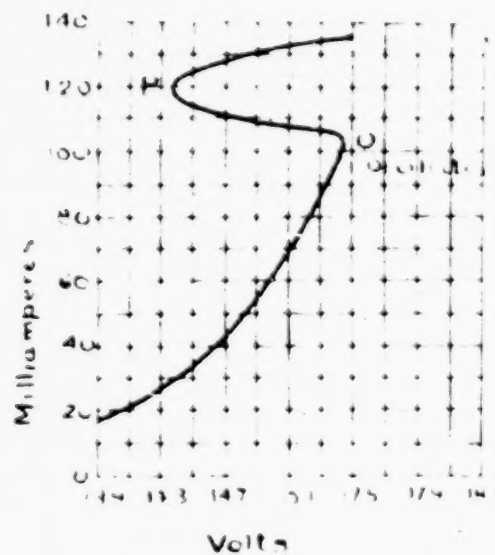


Fig. 5

Left two electrode tube

MECHANICAL DRAWING E



Fig. 1

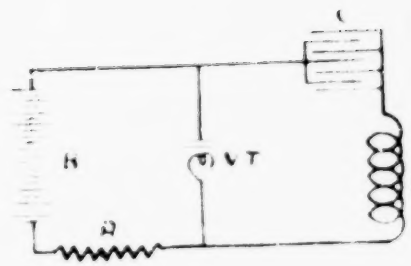


Fig. 2

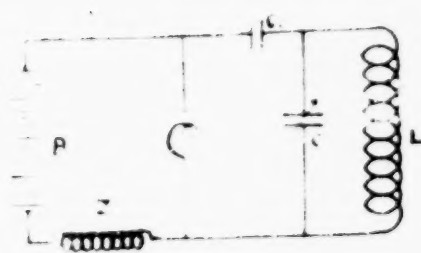


Fig. 3

## MILLER DRAWING F

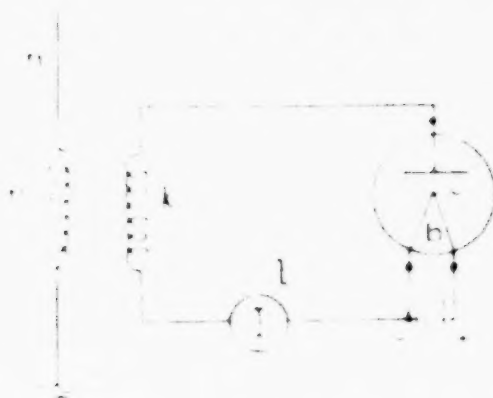


Fig. 1

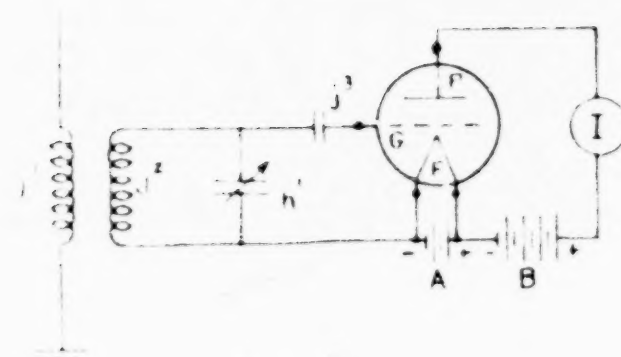


Fig. 2

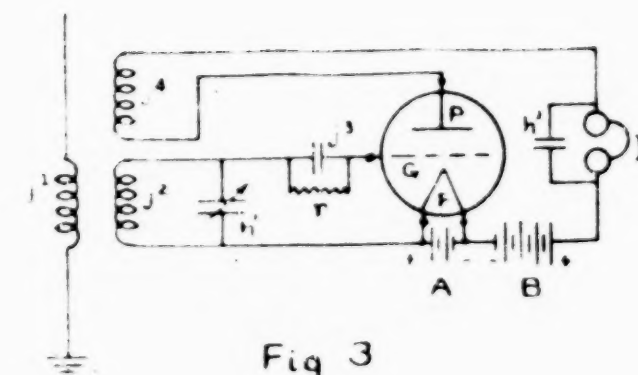


Fig. 3

## MILLER DRAWING 3

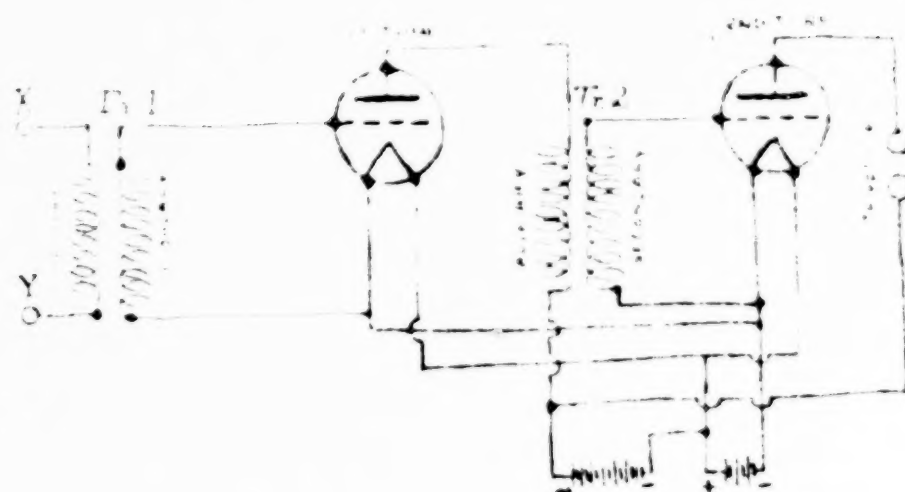


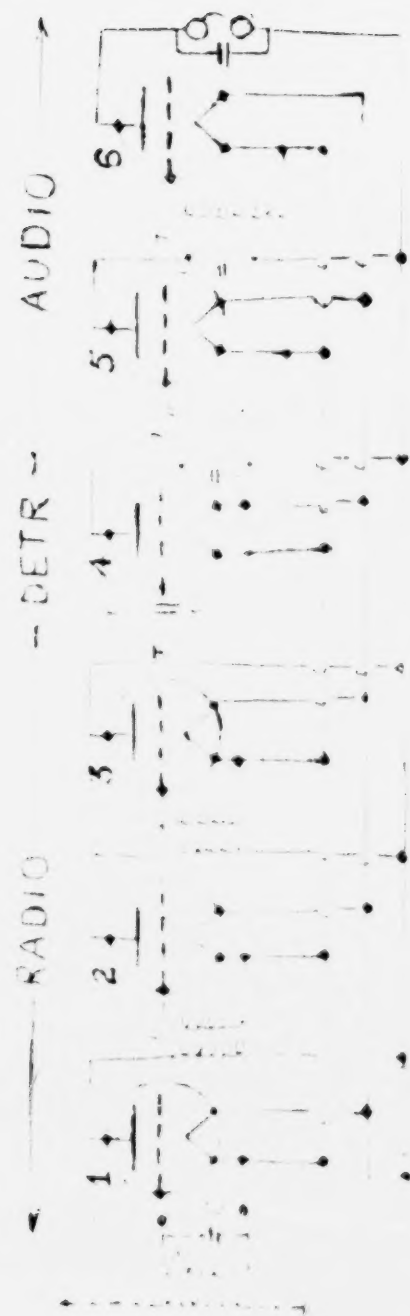
FIG. 1. PLATE BAT. FIL. BAT.

6X4 (TYPE SE 1000) 6AR5 (TYPE SE 1000)



FIG. 2.

MILLER DRAWING H



RADIO-AUDIO AMPLIFIER

## MILLER DRAWING I

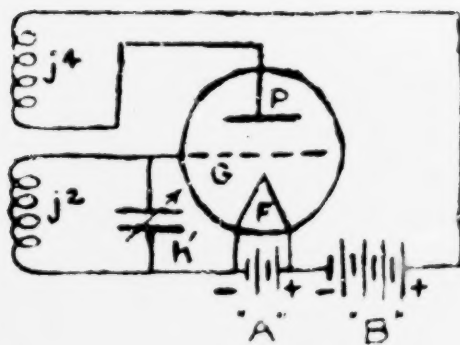


Fig. 1

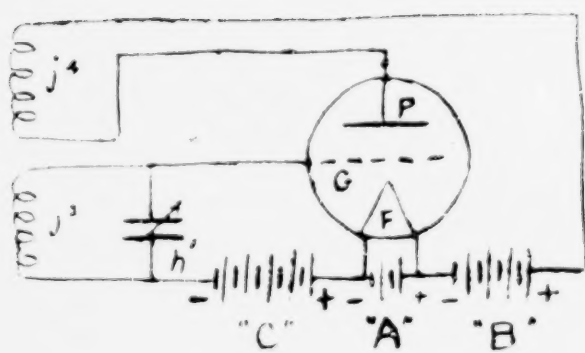


Fig. 2.

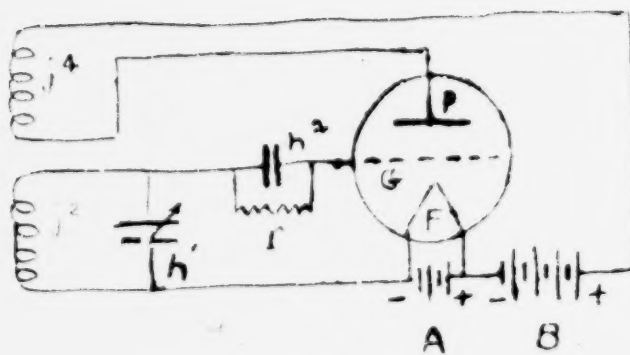


Fig 3.

## MILLER DRAWING J

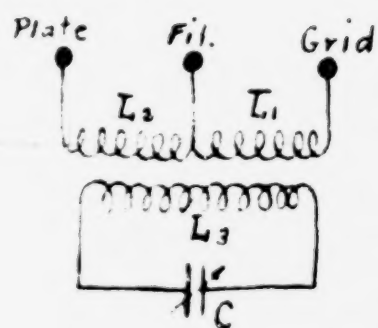


Fig. 1. Meissner.

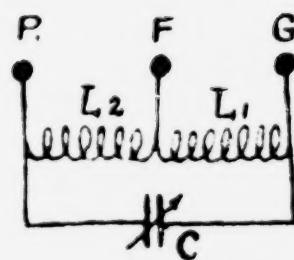


Fig 2. Hartley.

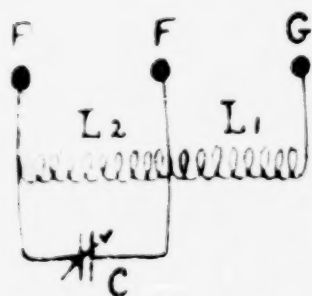


Fig. 3. Tuned Plate

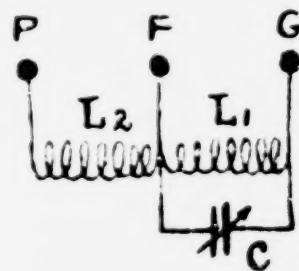


Fig. 4. Tuned Grid.

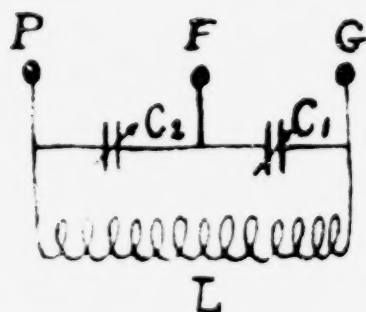


Fig. 5 Colpitts.

## MILLER DRAWING K

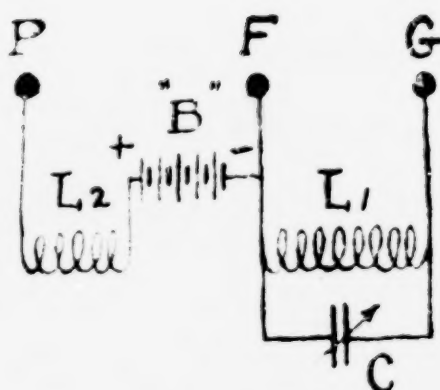


Fig. 1. Series "B" Battery.

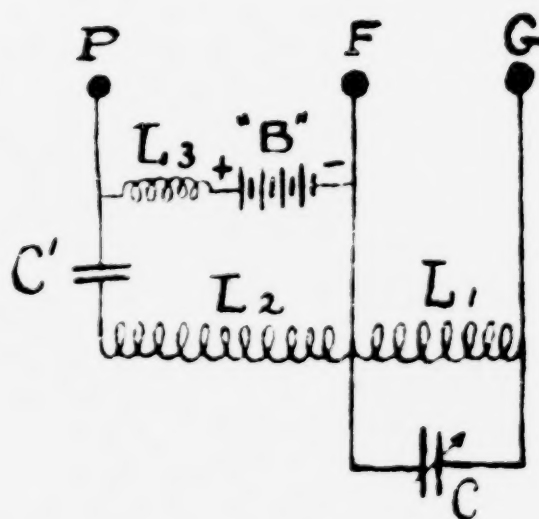


Fig. 2 Parallel "B" Battery.

# MILLER DRAWING L

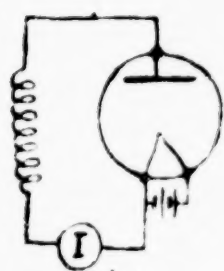


Fig 1

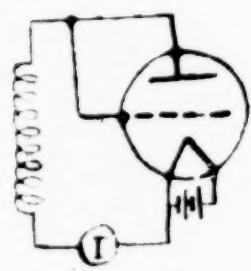


Fig 2

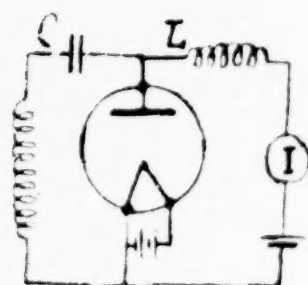


Fig 3

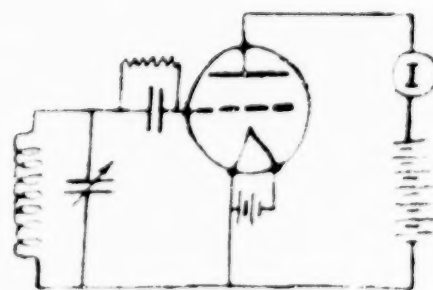


Fig 4

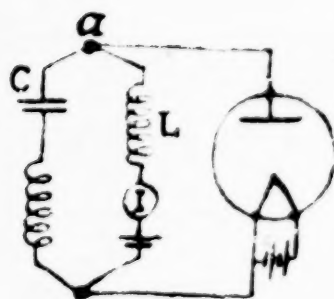
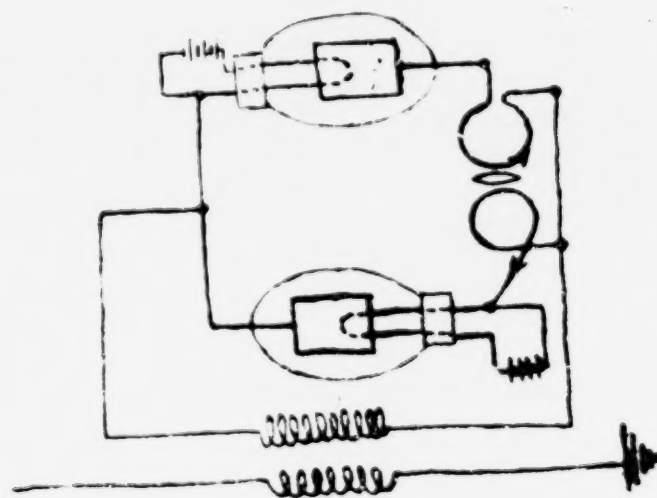
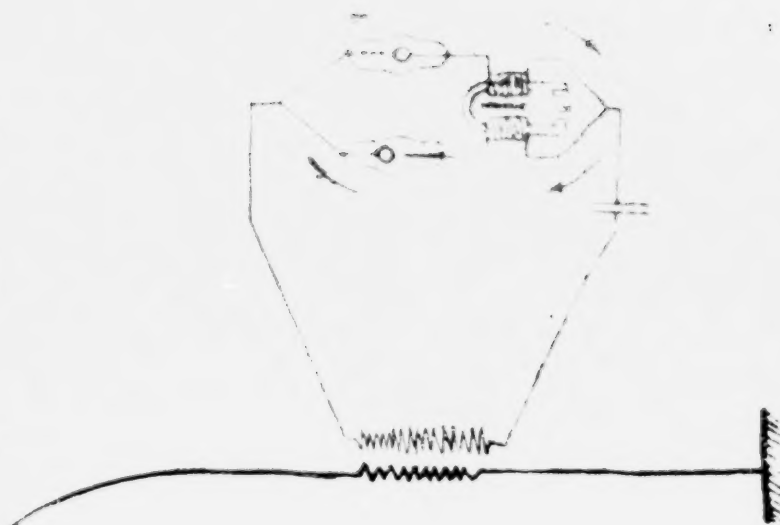


Fig 3a

# MILLER DRAWING M



*Fleming.*



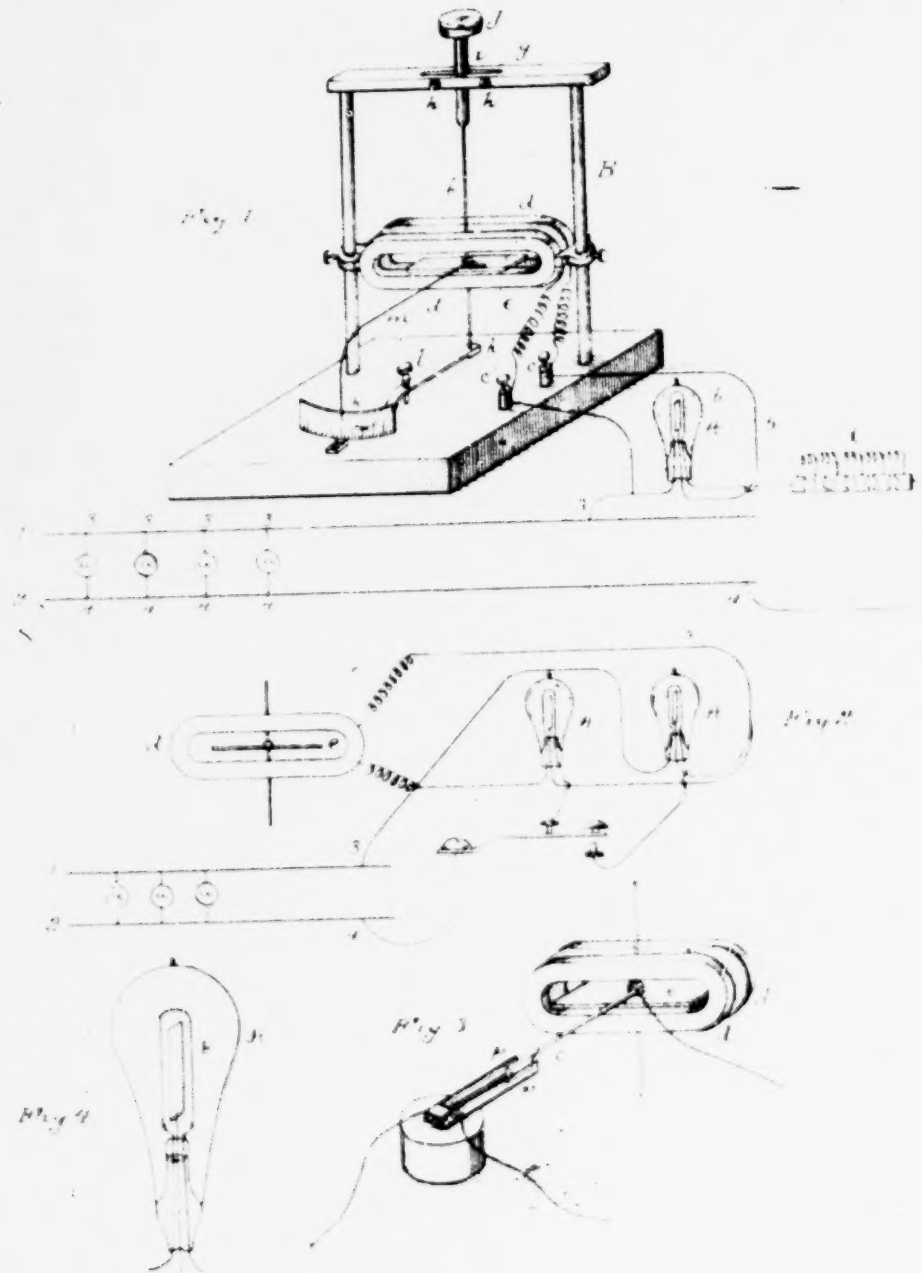
*Valbreuze.*

(No Model.)

T. A. EDISON.  
ELECTRICAL INDICATOR.

No. 307,031.

Patented Oct. 21, 1884.



ATTEST  
*[Signature]*  
*[Signature]*

INVENTOR  
*[Signature]*  
*[Signature]*

## UNITED STATES PATENT OFFICE.

THOMAS A. EDISON, OF MENLO PARK, NEW JERSEY.

## ELECTRICAL INDICATOR.

SPECIFICATION forming part of Letters Patent No. 397,031, dated October 21, 1888.

Application filed November 11, 1887.

*To all whom it may concern:*

Be it known that I, THOMAS A. EDISON, of Menlo Park, in the county of Middlesex and State of New Jersey, have invented a new and useful Improvement in Electrical Indicators, (Case No. 603,) of which the following is a specification.

The object of my invention is to produce an efficient apparatus for indicating variations of electro-motive force in an electric circuit, preferably for use in connection with systems of electrical distribution to show the changes in pressure in the various parts of the district. The apparatus is also capable of use in automatically regulating the electro-motive force to correspond with such variations. I have discovered that if a conducting substance is interposed anywhere in the vacuous space within the globe of an incandescent electric lamp, and said conducting substance is connected outside of the lamp with one terminal, preferably the positive one, of the incandescent conductor, a portion of the current will, when the lamp is in operation, pass through the shunt circuit thus formed, which shunt includes a portion of the vacuous space within the lamp. This current I have found to be proportional to the degree of incandescence of the conductor or candle-power of the lamp.

My invention consists in the utilization of this discovery for indicating or regulating variations in electro-motive force, or for affecting electrical apparatus in any desired manner. By connecting a device for indicating current changes in the shunt circuit, changes in the candle-power of the lamp, and consequently in the electro-motive force of the source of supply, are made apparent; or if, instead of an indicating device, the variations in electro-motive force are made to affect current-controlling apparatus, automatic regulators or other electrical apparatus may be controlled thereby.

In applying my invention to a system of incandescent electric lighting I place a standard lamp having within its globe a piece of platinum, preferably a thin plate, though platinum wire may be used, placed preferably between the limbs of its carbon conductor, such platinum piece being in connection with the circuit whose electrical condition is to be

observed, connecting said terminals similarly to those of the other lamp of the system, and making an additional connection from the positive terminal, preferably of the lamp circuit, to one terminal of a galvanometer or other indicator, and from the platinum piece through a wire sealed in the glass to the other terminal of the galvanometer or indicator. The galvanometer, if one is used, is provided with a torsion deflector holding its needle at zero under a normal current, so that variations above or below the normal deflect the needle in one direction or the other. If the electro-motive force in the system, and consequently the candle-power of the lamps, increases, the indicating lamp varies with the rest, and the current from it to the galvanometer is increased, causing the deflection of the galvanometer needle; and conversely, a decrease in electro-motive force in the system produces an opposite deflection. The galvanometer needle may be made to close circuit in electrically operated devices for accomplishing the automatic regulation of the generator supplying current to the system, or for any other purpose.

My invention is illustrated in the annexed drawings.

Figure 1 is a diagram of the system and connections, with a view in perspective of the galvanometer; Fig. 2, a diagram of a modified arrangement; Fig. 3, a view showing the use of the galvanometer to close regulating or other circuits; and Fig. 4 a view of the indicating lamp.

1, 2 are main conductors of a system of electric lighting, and *a a* electric lamps connected across them in multiple arc circuits 3, 4. *A* is a lamp similarly connected, and similar in every way to the other lamps, except that it has a piece of platinum, *b*, placed between the limbs of its incandescent conductor, while a wire, 5, attached to said platinum, is sealed in the glass of the globe with the wires 3, 4. The wire 5 leads to the binding post *c*, while a wire, 6, connected with the positive wire 3 of the lamp, leads to the binding post *c'*. These binding posts are the terminals of a galvanometer which consists of coils *d d* and a needle, *e*, carried by a torsion wire, *f*. The parts are held in a frame, *B*. The upper cross bar of the frame is split at *g*, the split being held to-

gether by screws *h h*, and the torsion-wire is attached to the smooth stud *i*, which is held by friction in the split, its torsion being adjusted by turning the thumb nut *j*. A spring, *k*, is attached to the other end of the torsion-wire, serving to keep said wire stiff, and the tension of the spring is adjusted by means of nut *l*. A pointer, *m*, extends from the needle to indicate its variations upon a scale.

*n*. The torsion of the wire *f* is so adjusted as to hold the needle and the pointer centrally with a normal current—that is, when the lamps of the system are at their normal candle power—and, as previously explained, any variations in the electro motive force of the system causing changes in the candle power of the lamps will produce deflections of the galvanometer needle, which deflections will be indicated on the scale.

Instead of simply causing the variations to be indicated on the scale, a circuit controlling arm, *o*, Fig. 3, may be carried by the needle, which may close circuit at contacts *p*, or in any other suitable manner to electrical devices for automatically regulating the electro motive force of the system, to electrically operated indicating devices, or to any electrically operated apparatus.

For regulating a dynamo electric machine, a mechanism such as shown in my Patent No. 287,524 may be used, the lamp *A* and galvanometer of the present apparatus being used in place of the pressure magnet *B* of said patent, the working magnets *C C* of said patent being located in the two circuits, closed by arm *o* of the present apparatus, which takes the place of the armature lever of said pressure-magnet *B*. An adjustable resistance, *q*, may be placed in circuit with the lamp *A*, to maintain said circuit at the standard lamp resistance.

In Fig. 2 a lamp, *A'*, is shown placed in a shunt around the lamp *A*. The lamp *A* being constantly in use, lamp *A'* is occasionally placed in circuit instead, so by observing its candle power it may be determined whether or not the resistance of the lamp *A* has changed.

What I claim is—

1. The combination of an incandescent electric lamp, a circuit including the vacuous space within the globe of said lamp, and electrical apparatus controlled by the current in such circuit, substantially as set forth.

2. The combination, with a system of electrical distribution, of an indicating or regulating apparatus therefor, comprising a standard lamp, a circuit including the vacuous space within the globe of said lamp, and electrical apparatus controlled by the current in such circuit, substantially as set forth.

3. The combination, with an incandescent electric lamp of a circuit having one terminal in the vacuous space within the globe of said lamp, and the other in connection without the lamp with one side of the lamp-circuit, substantially as set forth.

4. The combination, with an incandescent electric lamp, of a circuit having one terminal in the vacuous space within the globe of said lamp, and the other in connection without the lamp with the positive side of the lamp-circuit, substantially as set forth.

5. The combination, with an incandescent electric lamp, of a circuit having one terminal in the vacuous space within the globe of said lamp, and the other connected with one side of the lamp-circuit, and electrically controlled or operated apparatus in said circuit, substantially as set forth.

6. The combination, with an incandescent electric lamp, of a piece of conducting material placed in the vacuous space within its globe, and a conductor connected therewith and passing through and sealed in the glass of the lamp, substantially as set forth.

7. In a system of electrical distribution, the combination, with incandescent electric lamps connected in multiple arc, of a similar lamp similarly connected, a circuit having one terminal in the vacuous space within the globe of said lamp, and the other connected with one side of the lamp circuit, and electrically-operated apparatus in said circuit, substantially as set forth.

8. The combination, with an incandescent electric lamp, of a piece of conducting material placed between the sides of the incandescent loop, and a conductor leading therefrom to the exterior of the lamp, substantially as set forth.

This specification signed and witnessed this 2d day of November, 1883.

THOS. A. EDISON.

Witnesses:

H. W. SEELY,

EDWARD H. PYATT

No. 879,532.

PATENTED FEB. 18, 1908.

L. DE FOREST.  
SPACE TELEGRAPHY.  
APPLICATION FILED JAN. 29, 1907.

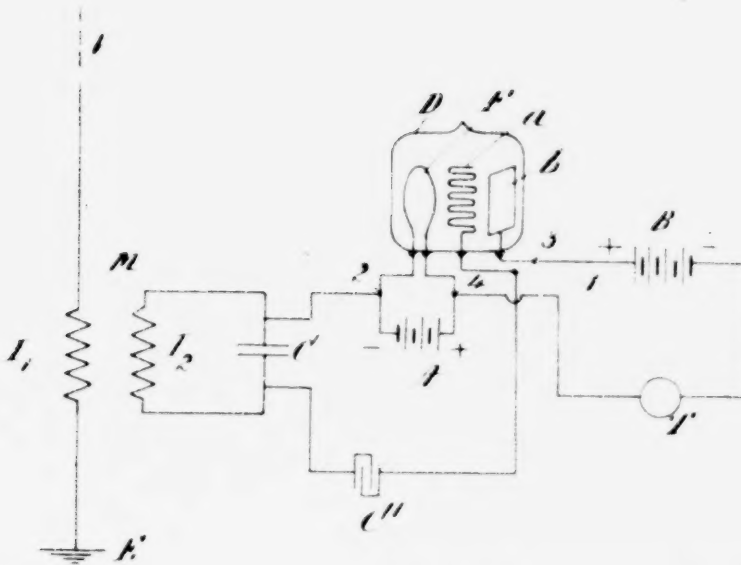


Fig. 1.

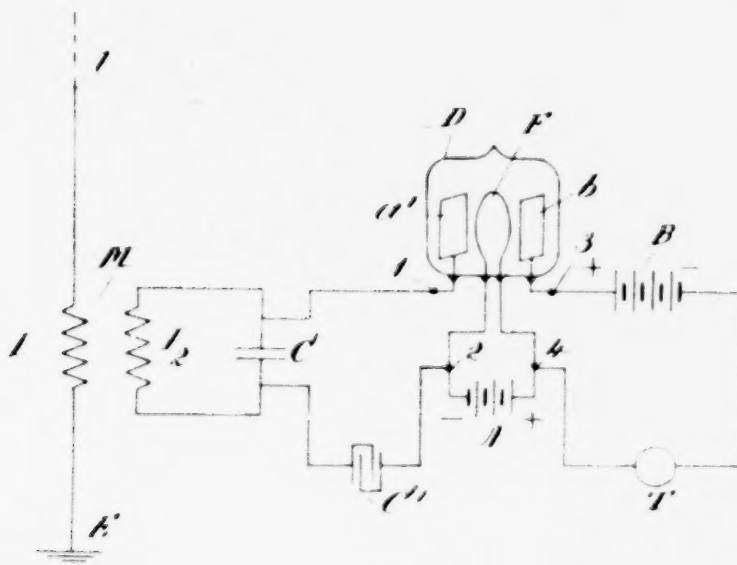


Fig. 2.

WITNESSES:-  
E. B. Tynkison  
Patrick J. Conroy

INVENTOR:  
Lee de Forest  
by Leo K. Woodward,  
Attor.

# UNITED STATES PATENT OFFICE.

13360

LEE DE FOREST, OF NEW YORK, N. Y., ASSIGNOR, BY MESNE ASSIGNMENTS, TO DE FOREST RADIO TELEPHONE CO., A CORPORATION OF NEW YORK.

## SPACE TELEGRAPHY.

No. 879,532.

Specification of Letters Patent.

Patented Feb. 18, 1908

Application filed January 29, 1907. Serial No. 354,662.

*To all whom it may concern:*

Be it known that I, LEE DE FOREST, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented a new and useful improvement in Space Telegraphy, of which the following is a specification.

My invention relates to wireless telegraph receivers or oscillation detectors of a type heretofore described in my prior Letters Patent Nos. 824,637, June 26, 1906 and 836,070, November 13, 1906.

The objects of my invention are to increase the sensitiveness of oscillation detectors comprising in their construction a gaseous medium by means of the structural features and circuit arrangements which are hereinafter more fully described.

My invention will be described with reference to the drawings which accompany and form a part of the present specification, although it is to be understood that many modifications may be made in the apparatus and systems herein described without departing from the principles of my invention.

In the drawings, Figure 1 represents a diagram a wireless telegraph receiving system comprising an oscillation detector constructed and connected in accordance with the present invention and Fig. 2 represents a space telegraph receiving system having a modified form of oscillation detector connected therein in a manner which constitutes one of the subjects matter of said invention.

V I, E is an elevated conductor system including the elevated conductor V, earth connection E, and primary I, of the transformer M, the secondary I, of which forms part of the tuned receiving circuit I, C. It will be understood of course that the aforesaid tuned receiving circuit may be associated with the elevated conductor system in any suitable manner.

D represents an evacuated vessel, preferably of glass, having sealed therein three conducting members, F, a and b, in Fig. 1 and F, a' and b in Fig. 2. The conducting member or electrode F is shown as consisting of a filament, preferably of metal, which is connected in series with the battery A or other source of electrical current of sufficient strength to heat said filament, preferably to incandescence. The conducting member b, which may be a plate of platinum, has one

end brought out to the terminal 3. Interposed between the members F and b is a grid-shaped member a, which may be formed of platinum wire, and which has one end brought out to the terminal 1. The local receiving circuit, which includes the battery B, or other suitable source of electromotive force, and the signal indicating device T, which may be a telephone receiver, has its terminals connected to the plate b and filament F at the points 3 and 4 respectively. The means for conveying the oscillations to be detected to the oscillation-detector, are the conductors which connect the filament F and grid a to the tuned receiving circuit and, as shown, said conductors pass from the terminals 2 and 1 to the armatures of the condenser C.

I have determined experimentally that the presence of the conducting member a, which as before stated may be grid-shaped, increases the sensitiveness of the oscillation detector and, inasmuch as the explanation of this phenomenon is exceedingly complex and at best would be merely tentative, I do not deem it necessary herein to enter into a detailed statement of what I believe to be the probable explanation.

In associating an oscillation detector of the above mentioned type, said detector being now commonly known as the audion, with a closed tuned circuit, it will be noted by reference to Fig. 2, that the secondary I, closes a circuit containing a battery shown at B through the electrode b, conducting member a' and the conducting gaseous medium intervening between said electrode and member. Also by reference to Fig. 1, it will be seen that a similar closed circuit exists between said battery, and the electrode b and conducting member a. In order to close each of said circuits to the passage of direct current from the aforesaid battery there-through, or to prevent the development of a difference of potential between the members a and b, or between a' and b, or to prevent the members a or a' from receiving an electrical charge from said battery, I insert the condenser C in said otherwise mechanically closed circuit and find that the presence of said condenser produces a great increase in the sensitiveness of the oscillation detector as determined by the very marked increase in the sound produced in the telephone T

evacuated vessel, an electrode inclosed therein, means for heating said electrode, a second electrode inclosed within said vessel, a local circuit having its terminals electrically connected to said electrodes, said local circuit including a source of electromotive force and a signal indicating device, a grid of conducting material inclosed within said vessel and located between said electrodes, and means for conveying the oscillations to be detected to the heated electrode and grid.

14. An oscillation detector comprising an evacuated vessel, two electrodes, one of which is a filament, inclosed within said vessel, means for heating said filament, and a conducting member inclosed within said vessel and interposed between said electrodes.

15. An oscillation detector comprising an evacuated vessel, two electrodes inclosed within said vessel, means for heating one of said electrodes, a grid of conducting material inclosed within said vessel and interposed between said electrodes, a local circuit connecting said electrodes, and a source of electromotive force and signal indicating device in said local circuit.

16. An oscillation detector comprising an evacuated vessel, two electrodes, one of which is a filament, inclosed within said vessel, means for heating said filament, and a grid of conducting material inclosed within said vessel and interposed between said electrodes.

17. An oscillation detector comprising an evacuated vessel, two electrodes inclosed within said vessel, means for heating one of said electrodes, a conducting member inclosed within said vessel and interposed between said electrodes, and a local circuit including a source of electromotive force connecting said electrodes.

18. An oscillation detector comprising an

evacuated vessel, two electrodes inclosed within said vessel, means for heating one of said electrodes, a grid of conducting material inclosed within said vessel and interposed between said electrodes, a local circuit including a source of electromotive force connecting said electrodes and a signal indicating device associated with said local circuit.

19. An oscillation detector comprising an evacuated vessel, two electrodes, one of which is a filament, inclosed within said vessel, means for heating said filament, a grid of conducting material inclosed within said vessel and interposed between said electrodes and a local circuit including a source of electromotive force connecting said electrodes.

20. An oscillation detector comprising an evacuated vessel, two electrodes inclosed therein, means for heating one of said electrodes, a conducting member inclosed within said vessel, a closed oscillation circuit, a circuit connecting one element of said oscillation circuit with one of said electrodes and said conducting member, and a condenser in said circuit.

21. An oscillation detector comprising an evacuated vessel, two electrodes inclosed therein, means for heating one of said electrodes, a conducting member inclosed within said vessel, a closed oscillation circuit, a circuit connecting one element of said oscillation circuit with one of said electrodes and said conducting member, a condenser in said circuit, a signal indicating device and a circuit connecting said device with the other of said electrodes and said conducting member.

In testimony whereof, I have hereunto subscribed my name this 21st day of Dec. 1906  
LEE DE FOREST

Witnesses:  
THOMAS L. GALLAGHER,  
HANS W. GOETZE.

[fol. 2892]

## DEFENDANT'S EXHIBIT I.

*The Thermionic Vacuum Tube and its Applications*

By H. J. Van Der Bijl, M.A., Ph.D., M.Am.I.E.E., M.I.R.E.,  
Mem. Am. Phys. Soc., Scientific & Technical Adviser,  
Dept. of Mines & Industries, Union of South Africa, Late  
Research Physicist, American Tel. & Tel. Co. and Western  
Electric Co., New York. First Edition. McGraw-Hill  
Book Company, Inc., New York, 239 West 39th Street,  
London: 6 & 8 Bouverie St., E.C. 4, 1920

If we are concerned only with electrodes that can be heated by passing a current through them we can adopt the practice that lamp manufacturers have been following for the last twenty or thirty years, viz., passing a current through the electrodes to raise them to a higher temperature than they attain during operation, and by baking the bulbs in ovens to as high a temperature as the glass can stand. But thermionic devices of the most commonly employed types also contain electrodes (anode and grid) which cannot be heated by passing a current through them. These electrodes can be heated during evacuation by electron bombardment; that is, by passing a thermionic current from cathode to anode through the tube. The amount of this current and the voltages applied should be higher than the values used when the tube is subsequently put in operation. Although these tubes operate under the condition that gas has no influence on the discharge, the operation of the tube will always be better understood if the effects of small traces of gases are known. These effects are therefore discussed in Chapter V.

The thermionic valve (by this we mean a two-electrode thermionic tube) is still used at the present time as a rectifier of alternating current, and as such it is a valuable instrument, and is capable of performing useful functions. Its operation and some of its uses are discussed in Chapter VI.

As a detector of electromagnetic waves, the valve has no commercial value. The device which is used for detecting [fol. 2893] purposes is the three-electrode tube which in addition to the anode and hot cathode, also contains a grid to control the flow of electrons from cathode to anode. The grid was inserted by de Forest in 1907, who called the device the "Audion" and it is the insertion of the grid which has

made the thermionic tube of such great value. Since the flow of electrons from filament to anode or plate can be varied by applying potential variations to the grid, the circuit in which this tube is used consists of two branches: the output circuit connecting the filament to the plate through a current or power indicating device and the input circuit connecting the filament to the grid through the secondary of a transformer or other means of supplying potential variations to the grid.

The audion was first used as a radio detector but was subsequently found to be capable of performing a number of other important functions. In fact, the insertion of the grid into the valve resulted in a device of tremendous potentialities—one that can justly be placed in the same category with such fundamental devices as the steam engine, the dynamo and the telephone.

Since a mere variation in the potential of the grid produces a variation in the plate current, it could reasonably be expected that more power would be developed in the output circuit than the power expended in the input circuit, and this has actually been found to be the case. The operation of the tube as an amplifier is simpler than its operation as a detector. I have therefore found it best first to discuss the manner in which the tube operates as an amplifier, reserving its operation as detector for discussion in a later chapter. Chapter VII not only describes the amplifier and the manner in which it operates, and the circuits that can be used, but also discusses the characteristics of the three-electrode tube.

Since the power in the output circuit of the audion tube is greater than the power expended in the input, it is possible to increase the degree of amplification by feeding back part of the energy in the output to the input. If the proportion of the energy thus returned to the input circuit is large enough and the phase relations of the currents in the output and input circuits are right, the tube can be made to produce sustained oscillations. What is usually done is to connect the tube in an oscillation circuit having the desired capacity and inductance, and then couple the output circuit to the input in such a way that current variations in the output circuit cause potential variations to be impressed on the grid. There are a great variety of circuits whereby this can be accomplished. To make a three-electrode tube produce sustained oscillations is an extremely simple matter.

but to make it operate in the most efficient way as an oscillation generator requires a knowledge of the various factors that influence its operation as such. These matters are discussed in Chapter VIII.

When the tube is used as an amplifier or oscillation generator it is desirable that the characteristic representing the relation between the plate current and the potential of the plate or grid be as nearly linear as possible. On account of the negative space charge of the electrons in the space [fol. 2894] between filament and anode the characteristic is not linear, but convex towards the axis of voltage. When the applied voltage becomes sufficiently high to attract the electrons over to the plate as fast as they are emitted from the filament, the characteristic curve becomes concave towards the voltage axis and finally becomes nearly horizontal, thus giving the saturation current. In order to obtain the best operation of the tube as an amplifier, it is necessary to straighten out the characteristic of the plate circuit. Means whereby this can be done are discussed in Chapter VII. The curvature of the characteristic causes the shape of the current wave in the output to be distorted, and is therefore a very undesirable feature of the audion as an amplifier. On the other hand, the fact that the characteristic is curved simply increases the number of uses to which the audion can be put. Its ability to detect electromagnetic waves lies in the curvature of its characteristic. This also makes it possible to use the tube for modulating high frequency waves for the purpose of radio or carrier telephony and telegraphy. The processes involved in detection and modulation are identical, and these are therefore treated together in Chapter IX.

In Chapter X are described a few miscellaneous applications of the thermionic tube. This list is intended to exemplify the manner of applying the principles of the tube and does not make any pretense at being complete. It is believed that the number of such applications is destined to increase considerably and that the tube will become of increasing importance not only in engineering practice, but also in university and college laboratories.

A large number of names have been used to designate the three-electrode type of thermionic tube, such as audion, plotron, triode, thermionic valve, etc.—an impressive array of names which certainly attests the importance of this device. To forestall any possible confusion in the mind of

the uninitiated reader I may say that these names all apply to one and the same thing, namely the audion or three-electrode tube discussed in the following pages.

The major portion of the development of the audion has taken place in the past eight years, but while the number of applications of the tube increases almost daily, we must frankly admit that as far as the tube itself is concerned, it was developed to a full grown and powerful instrument as early as 1914. The rapid development of this device, both in the United States and Europe and the popularity it has gained, are due to a number of factors that have concurred to place it in the foreground. One obvious reason of course, is its ability to perform such a large number

Referring now to Fig. 12, it is seen that there is a definite frequency  $\nu_0$  of the light at which the voltage necessary to drive the electrons back becomes zero. This means that for frequencies lower than this value no electrons escape at all. Putting  $V=0$  in equation (21) we get:

$$\nu_0 = \frac{e}{h} \phi \quad (22)$$

[fol. 2895] This limiting frequency, commonly referred to as the *photo-electric long wavelength limit* is a fundamental property of solids and, is equal to a constant multiplied by the electron affinity—the same constant that plays such an important part in the emission of electrons from hot filaments in the thermionic vacuum tube.

The quantities  $h$  and  $e$  are universal constants, that is, their values are independent of the matter under investigation and the conditions of the experiments. Their values are  $h=6.55 \times 10^{-27}$  erg. sec., and  $e=4.77 \times 10^{-10}$  E.S. units.

22. *Control of Space Current by Means of an Auxiliary or Third Electrode.*—A convenient and what has proved to be a very valuable means of varying a space current is obtained by placing a third electrode in the neighborhood of the cathode and applying potential variations to it. This scheme was used by de Forest to control the electron discharge in his audion detector in 1907.<sup>1</sup> He later gave the

<sup>1</sup> Lee de Forest, U. S. Patent No. 841387, 1907.

auxiliary electrode the form of a wire gauze or grid placed in the path of the discharge between cathode and anode.<sup>2</sup> About the same time von Baeyer<sup>3</sup> also used an auxiliary electrode to control a thermionic current from a hot filament. In von Baeyer's arrangement the anode was a cylinder and the cathode a wire placed along its axis. The third electrode was a wire gauze bent into the form of a cylinder and placed between cathode and anode. A similar scheme was also used by Lenard<sup>4</sup> in 1902 in connection with photo-electric experiments. It is hardly necessary to say that the insertion of the grid has made the audion a device of immense practical importance and enabled it to perform functions that would otherwise have been impossible. The relation between current and voltage is given by a curve such as *AB* (Fig. 34). The gas-free device, on the other hand, has a characteristic similar to *OC*. The difference between tubes containing these characteristics becomes apparent when we consider the corresponding a-c. resistances.

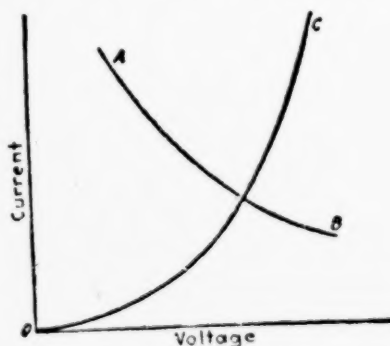


FIG. 34

The a-c. resistance for small current or voltage variations at any definite voltage is given by the reciprocal of the slope of the characteristic at a point corresponding to that voltage. Since the slope of the curve *AB* is negative, the arc has a negative resistance, while the resistance of a gas-free tube is positive.

It is the negative resistance of the arc which enables it to produce sustained oscillations. It will be shown in Chapter VIII that a device containing only two electrodes can only produce sustained oscillations if it has a negative resistance or a falling characteristic. The principle involved in the production of sustained oscillations by the audion or three-[fol. 2896] electrode thermionic tube is entirely different

<sup>2</sup> Lee de Forest, U. S. Patent No. 879532, 1908.

<sup>3</sup> O. von Baeyer, *Verh. d. D. Phys. Ges.*, Vol. 7, p. 109, 1908.

<sup>4</sup> P. Lenard, *Ann. d. Phys.*, Vol. 8, p. 149, 1902.

and depends on the controlling action of the grid on the electron flow from filament to anode.

radio detector. The circuit in which Marconi used this device as a radio detector is shown in Fig. 39.

45. *Valve Detector with Auxiliary Anode Battery.*—By our present standard of measurement the two-electrode

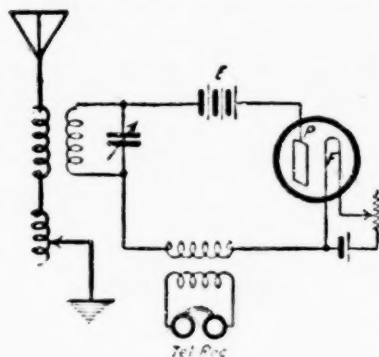


Fig. 40.

tube is a very inefficient detector. It can be, and has been used more efficiently by operating on a chosen point of the current-voltage characteristic, thus making it fall in the class of rectifiers given by condition (4) instead of that represented by condition (3). This can be done by inserting a local battery in the circuit as shown in Fig. 40.<sup>5</sup>

The operation of the device when used this way can be understood from the following: By the insertion of the battery  $E$  there is established in the circuit  $FPE$  a constant direct current which has a finite value even when no oscillations are impressed from the antenna. The current through the device can therefore be represented by a function of the form

$$I_f + i = f(E + e \sin pt), \quad (5)$$

where  $E$  is the local source of direct voltage,  $I$  the direct current due to  $E$  and  $i$  the superposed a-c. due to  $e$ . This can be expanded into a powerseries,

$$f(E + e \sin pt) = f(E) + f'(E)e \sin pt + f''(E) \cdot \frac{e^2 \sin^2 pt}{2} + \dots + f^{(n)}(E) \frac{e^n \sin^n pt}{n}.$$

<sup>5</sup> See Lee de Forest, Proc. A. I. E. E., Vol. 25 p. 719, 1906, and J. A. Fleming, Proc. Roy. Inst., Great Britain, June, 1919, p. 677.

## Chapter VIII—The Vacuum Tube as an Oscillation Generator

79. *Introductory.*—Since the three-electrode tube can operate as an amplifier, the energy in the output circuit is greater than that in the input circuit. Hence, if part of the energy in the output be returned to the input, there will — a further amplification of energy resulting in an increased output. If the amplified energy gets back to the input in sufficient amount, and if the phase relations of the output and input currents are right, there will be a constant re-amplification and feeding back of energy from the output to the input, and the device will then produce sustained oscillations without it being necessary to supply potential variations to the grid by external means. In other words, the device will then operate as an oscillation generator. [fol. 2897] The frequency of the oscillations will be determined by the constants of the circuit, while their intensity will depend on the amount of energy fed back to the input, the shape of the characteristic curve, and the rate at which power is dissipated. There is a variety of circuit arrangements whereby this can be done. These circuits can all be divided into three main groups in which part of the energy in the output is returned to the input: (1) by resistance coupling, such as is explained, for example, in connection with Fig. 145, page 259; (2) inductive coupling; (3) capacitive coupling between output and input.

In the present chapter we shall briefly discuss the conditions that must be satisfied in order to use the three-element tube to produce oscillations of a definite frequency and amplitude. A large amount of work has been done on this phase of the subject, and no attempt will be made here to enter into a full discussion of these investigations. It is believed rather that an explanation of the fundamental principles that govern the production of sustained oscillations with the three-electrode tube, and an indication

. . . . .

From this we see that in order to obtain sustained oscillations from a device having only two electrodes, it is necessary that the device shall have a negative resistance. Examples of negative resistances have already been given in the previous pages. Thus an arc may have a negative resistance, its characteristic being of the form shown by the

curve  $AB$  in Fig. 34. The resistance is given by the slope of the characteristic and this is a negative quantity for a characteristic of the kind shown. Fig. 16, page 48, shows another characteristic which over a region  $ABC$  has a negative slope and is obtained as the result of the emission of electrons from metals under the impact of electrons. Such characteristics as these are sometimes referred to as "falling characteristics."

The thermionic valve does not show a falling characteristic like the curve  $AB$  of Fig. 34, when it is sufficiently well evacuated to prevent the effects of ionization by collision from appreciably influencing the discharge. The characteristics of thermionic valves are those given and discussed in the previous chapters and it will be seen that for such devices the resistance is always positive. It is, therefore, impossible to obtain sustained oscillations from a well-evacuated thermionic valve containing only two electrodes. If such a device contains an appreciable amount of gas during the operation, the characteristic becomes unsteady and sometimes, especially at the higher voltages, exhibits regions over which the slope is negative, and when operated over that region it is, of course, possible to obtain sustained oscillations. The condition which makes this possible in a two-electrode device is unfortunately due to the cause which makes such a device unsatisfactory; namely, the presence of too much gas in the device, thus causing unsteadiness of the discharge and making reproducibility practically impossible. If a controlling electrode or grid be added to the two electrodes of a valve, the operation becomes different and we now have a device which can produce sustained oscillations with facility while at the same time satisfying all the conditions that are necessary to secure satisfactory operation in every respect, namely, freedom of gas with consequent steadiness and reproducibility of results, and comparatively long life.

## 82. Condition for Oscillation for Three-Electrode Tube.—

Let us now consider a circuit like that shown in Fig. 152. This is one of a large number of possible oscillation circuits. It is

## DEFENDANT'S EXHIBIT M

*Proceedings of Physical Society of London, Vol. XXII,  
September 1910*

**XXV. On an Oscillation Detector actuated solely by Resistance-temperature Variations.** By W. H. Eccles, D.Sc.<sup>1</sup>

In a recent communication to the Physical Society<sup>2</sup> the properties of a type of iron-oxide coherer were discussed. The paper described experiments on coherers made by dipping a slightly oxidised iron wire into clean mercury, or by pressing a fine iron wire against a thinly oxidized iron plate, and the results were discussed mathematically. It was shown that in the case of the iron point and oxidized plate the whole of the experiments could be explained qualitatively on the assumption that the only electrical phenomena at play were the Joule effect and the resistance-temperature changes in the small mass of oxide between the metal electrodes. The hypothesis that was put forward must be summarized here. Let  $z$  be the resistance of that part of the detector where the current flow is so constricted that the Joule effect produces rise of temperature, and  $r$  the resistance of the remainder of the circuit. The resistance  $z$  is usually localized at the contact of the conductors that form the detector, and it varies with the temperature of the minute mass of matter at the contact; let  $\alpha$  be the coefficient of decrease of resistance with rise of temperature. The resistance  $r$  includes that of the bulk of the substances forming the detector, the leads and the telephone; it is supposed constant. Let  $c$  be the current when the electromotive force applied to the detector is  $\epsilon$ . Assume that the rate of loss of heat from the warmed contact is  $m\theta$ , where  $\theta$  is the temperature of the contact above that of the surroundings. Then it was shown that in the steady state

$$\epsilon = \left( \frac{\rho_0}{1 + q\alpha\theta^2} + r \right) c, \quad \dots \dots \dots (1)$$

<sup>1</sup> Read May 27, 1910.

<sup>2</sup> W. H. Eccles, "On Coherers," *Phil. Mag.* June 1910; *Proc. Phys. Soc.* vol. xxii. 1910.

where  $\rho_0$  is the resistance of the contact when cold and  $q$  is a constant. If the curve  $\epsilon = \rho_0 c / (1 + q\alpha c^2)$  be plotted with  $c$  as abscissa and  $\epsilon$  as ordinates, it is seen to rise from the origin of coordinates with an increasing gradient till at a definite value of  $c$  it becomes vertical. Then as  $c$  increases, the curve bends towards the axis of  $c$  and approaches it asymptotically. Along this latter part of the curve, increasing current is associated with decreasing electromotive force—an unstable state of affairs. Any conductor possessing a negative temperature-coefficient of resistance exhibits these properties. In such conductors an increase of current produces, in accordance with Joule's law, an increase of temperature, and consequently, a diminution of the resistance. The curve shows that after a certain stage is passed the diminution of the resistance which accompanies increasing current is great enough to lead to a catastrophe. Stability can, however, be obtained by introducing into the circuit of the variable resistance  $\rho$  a sufficiently large constant resistance  $r$ . The phenomenon resembles that of the electric arc. The unstable portion of the above curve corresponds, in fact, to the "falling characteristic" of the arc.

If the resistance  $r$  is large the  $c, \epsilon$  curve has a positive gradient throughout, and the gradient has a maximum at some value of  $c$ . Near this point the contact is found to work best as a detector of oscillations. The hypothesis put forward by the author supposes that a train of oscillations, by yielding its energy as heat to the contact, raises the temperature there and disturbs the existing equilibrium of current and voltage. The dissipation of a train of oscillations is accomplished in a time of the order of a fifty-thousandth of a second; the ensuing fluctuation of the current causes the sound in the telephone. In the paper cited, the energy  $w$  given to the telephone circuit was shown to be connected with the energy  $W$  delivered by the train of waves by the equation

$$w = m(W - a), \quad (2)$$

where  $m$  and  $a$  are constants for any fixed value of the current. This theoretical conclusion agreed well with the experiments on an iron oxide coherer. The object of the present paper is to show that the above hypothesis holds good for a very different type of detector. All the well-known forms of "contact" detector consist of a contact between two substances that stand well apart in the thermo-

electric series, and the thermoelectric force plays a very important part in their operation. They are usually classed as "rectifying detectors" to distinguish them from such detectors as the coherers. In seeking a "rectifying detector" that would illustrate the above hypothesis, substances that stand far apart in the thermoelectric series must be avoided, for such substances would introduce Peltier effects that would tend to mask the resistance-temperature phenomena we wish to isolate. Even in the iron : iron-oxide : iron coherer it is possible that thermoelectric forces arise owing to unequal heating of the two iron to iron-oxide junctions. It occurred to me, therefore, to construct a detector out of one substance only. Accordingly a search was made for a substance possessing high, but not too high, resistivity, with large negative temperature-coefficient. Several such substances were found among the native crystalline oxides and sulphides. Most of these are anisotropic, and must on that account be avoided. Fortunately galena, the native sulphide of lead, has fairly high resistivity, a very large negative resistance coefficient, and crystallizes in the cubic system. A galena-galena detector was therefore constructed. Two pieces of galena cut from the same crystal were embedded in solder, mounted in a clamp, and brought into gentle contact. It was put into a wireless telegraph receiving set and was found to yield excellent signals when a current of proper magnitude was passed through it.

A few preliminary experiments showed that it was not easy to find two pieces of galena, which when placed together and submitted to positive and negative voltages in turn, exhibited perfect symmetry. The symmetry is always small, and is probably due to the rise of thermoelectric forces at the contact when it becomes heated by the steady current, and these forces are probably caused by slight variations in the chemical composition of the galena from point to point in the crystal. When a contact that gives symmetrical voltage-current curves is found, it constitutes a detector that operates only when a current is passing through it. The efficiency of the detector is the same for each direction of the current, and appears to be practically independent of the shape of the galena surfaces at the contact.

The experiments now to be described were made on selected galena-galena combinations in precisely the same

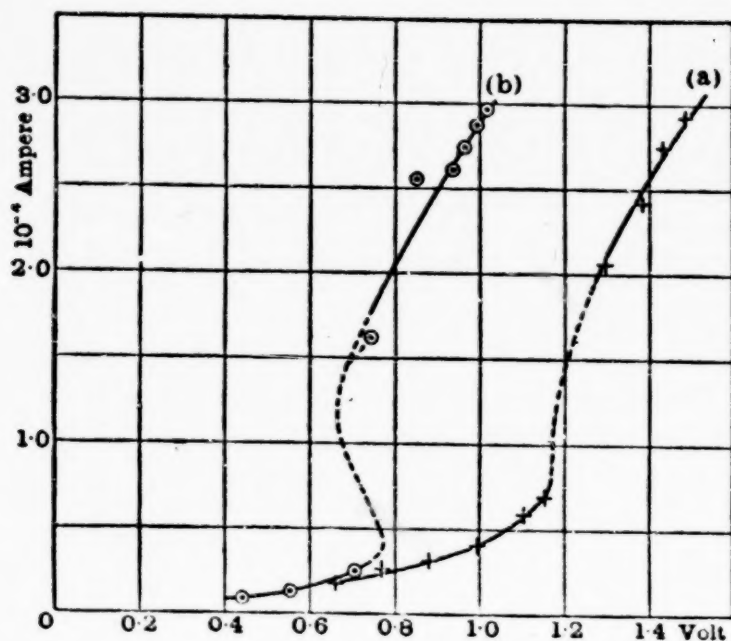


FIG. 1

way as the earlier experiments on the iron-oxide detectors. The diagram of the apparatus employed is shown in fig. 1 of the previous paper (Phil. Mag. June 1910, p. 872, & Proc. Phys. Soc. vol. xxii; p. 293). The mutual inductance between  $L$  and  $L'$  was 2500 cm. in obtaining the results described below.

[fol. 2901] The detector was placed at D and submitted to an electro-motive force from  $P_2$ , which was varied in steps from zero to about one volt positive or negative. At each step an observation was made of the steady current through the detector, and of the intensity of the sound produced in the telephone by electrical oscillations of amplitude fixed by the position of the jockey on  $P_1$ . The steady current observation was made by means of a shunted galvanometer kept connected in series with the telephone. The intensity of the sound was

## DEFENDANT'S EXHIBIT N

*Wireless Telegraphy with Special Reference to the  
Quenched-Spark System*

By Bernard Leggett, A. M. I. E. E., late Wireless Technical Staff, Messrs. Siemens Bros. and Co., Ltd., Late Officer in Charge of Trench Wireless, 1st Corps, B. E. F. London, Chapman & Hall, Ltd., 11 Henrietta St., W. C. 2, 1921

increase of the c. m. f. causes the passage of a current. Such increase may be due to a signal received upon an aerial and the passage of the current of the external c. m. f. is rendered audible by the telephone.

For good working the negative electrode should be a point of about .002 sq. mm. surface. These detectors are extremely sensitive, but require accessory regulating apparatus and attention, and are now largely replaced by contact detectors.

4. *Contact detectors.*—These are the detectors most used at the present day. They consist essentially of contact points between a suitable metal and crystal such as molybdenite or galena. Such a contact has the property of allowing oscillatory currents to pass in one direction and not the other, so rendering them aperiodic. The passage of these aperiodic currents may be heard by connecting a small condenser in circuit and shunting it with a telephone wound to the correct high resistance.

These detectors are the most sensitive for ordinary working, cannot be greatly damaged, are always ready for use, and require no auxiliary apparatus. They are therefore very widely used.

*The action of Crystal Detectors.*—Very many hypotheses have been put forward to explain the action of contact detectors, the chief views being that the phenomena depends on thermo-electric properties, photo-chemical properties, electrolysis in solids, electro-static attraction, etc.

The balance of evidence would seem to be that their action depends on electro-thermal phenomena. Such phenomena depends on:

1. The variation of resistance with temperature.
2. The Peltier effect, which may be expressed as the causation of an increase or decrease of temperature, when

an electrical current passes across a junction of two *different* metals. Conversely a current is generated when such junction undergoes a variation in temperature (made use of in the thermo-couple).

[fol. 2902] 3. The Thomson effect, which produces an electrical e. m. f. between different parts of the same metal at different temperatures.

Any or all of these phenomena appear to cause rectification of the oscillatory currents of wireless telegraphy. The elaborate consideration of these effects is primarily a matter of pure physics, and for further information the reader must be referred to Starling's *Electricity and Magnetism*."

The application of such phenomena to wireless reception is Boltzmann in 1890, would appear to be the first to apply gaseous tubes to wireless purposes, i. e. to detect Hertzian oscillations.

Zehnder, in 1892, improved Boltzmann's arrangement producing his "trigger-tube" (Fig. 72 (1)), in which a local circuit (F.E.G.) was so adjusted that its potential was just insufficient to break down the resistance of a gaseous tube. Complete breakdown resulted when a small additional potential was supplied by an Hertzian oscillator, represented by ABCD. The apparatus was used purely to detect the presence of oscillations, but was undoubtedly also an intensifying arrangement.

Whilst it was not thermionic, i. e. it did not utilise electrons given off from a heated filament, it is undoubtedly more allied to the present-day amplifier in its method of operation than the later two-electrode tube of Fleming.

In 1884, Edison, at the Philadelphia Exhibition, had exhibited an apparatus consisting of a plate between the limbs of the filament of an incandescent lamp (Fig. 72 (2)). He showed that if a galvanometer was connected between the plate and the negative end of the filament no current was shown, whereas when the plate and the positive end of the filament were connected, a current was obtained.

Since electrons had not yet been shown to exist no reason could be given for this effect, called the Edison effect, but which had also been independently shown in high vacua, by Elster and Geitel.

Fleming, in 1904, utilised the Edison effect, and Elster and Geitel's apparatus in a modified form, to produce a

wireless detector, rectification being brought about owing to the unidirectional conduction already mentioned. Fleming's arrangement is shown in Fig. 72 (3), and is in effect a reversal of the relative position of plate and filament in Edison's apparatus.

The Fleming valve was purely and simply a rectifier or detector. In no way was it an intensifying device, it did not use a very high vacuum, as is the case in the modern valves of Langmuir and Meissner, and was not a means of generating oscillations like these later valves.

Whilst Fleming must be credited as being the first to apply thermionic phenomenon to wireless detection, the claim that he is alone the originator of the present-day thermionic valve is rather exaggerated, since the intensifying properties of the present-day valve are far more important than its detecting properties, and as an intensifying arrangement, the Zehnder "trigger-tube" is more akin to the modern valve in principle.

[fol. 2903] As a detector the Fleming valve was fairly sensitive, but from the author's own personal experience, a result also noticed by Stanley, it was not so sensitive as a crystal detector. As well as being more sensitive, the crystal detector has the advantage of not requiring any heating battery, with consequent adjustment and maintenance troubles.

The next step in the development was due to de Forest who was the first to use the modern three-electrode valve for wireless work in his "Audion" patent of 1907. This arrangement (Fig. 72 (4)) is essentially the modern valve. It had a vertical filament, a zig-zag grid and a plate, and was certainly a great advance.

As far as the author can ascertain, and certainly from his patent specification, this valve did not, like some of his later ones, use an oxide coated filament. It was a vacuum tube but not of exceeding high vacua. De Forest would appear to have intended his device as a detector only, and did not recognise its possibilities as an intensifier, which it must undoubtedly have been.

Much controversy and litigation occurred over the patent aspects of the audion, Fleming claiming that it infringed his two-electrode valve, although he himself states "the Audion differs from the author's oscillation valve in having a grid and a plate sealed into the bulb, in place of a single metal cylinder surrounding the filament."

The result of this American litigation was that, whereas de Forest was prevented from using his valve, since it infringed Fleming's patent, on the other hand the Marconi Company, who were interested in Fleming's action, were equally prevented in using de Forest's three-electrode valve, which according to de Forest ("Electrician," p. 26, 1916) was their intention.

De Forest's letter referred to above should certainly be read before forming any opinion as to the relative value of claims regarding the origin of the valve. It certainly illustrates how patent litigation can retard scientific progress.

The whole situation regarding this controversy is best summed up in Mr. Justice Sargeant's words at the Chancery Division, on Fleming's application for extension of his 1904 patent: "I should hesitate to describe a three-electrode valve or de Forest valve as being a mere improvement in view of the great independent invention displayed in that device. I do not think that the valve would ever have come into being but for the previous invention of the 1904 Fleming valve, though it is of course obvious and admitted by the Petition, that where the de Forest

. . . . .

It will be most convenient to deal with each class of generator separately, before dealing with purely telephonic questions.

#### Arc-generators

In 1899 Mr. W. Duddell found that if a direct-current electric arc, such as that of an arc-lamp, is shunted by a circuit containing capacity  $C$  and inductance  $L$  (Fig. 180), [fols. 2904-2905] oscillations of a frequency, approximately

$$\frac{1}{2\pi\sqrt{LC}}, \text{ occur in the shunt circuit.}$$

The production of these oscillations is as follows:

On closing the shunt circuit, the flow into the condenser causes a drop in the flow of current into the arc. Consequently the temperature falls, and the resistance of the arc increases, becoming a greater fraction of the resistance of the main circuit. The resistance of the main circuit and the difference of potential between the arc carbons rises with a further production of flow into the condenser. Eventually

the accumulation of charge in the condenser raises the difference of potential between its plates to that between the carbons. This results in stopping the flow into the con-

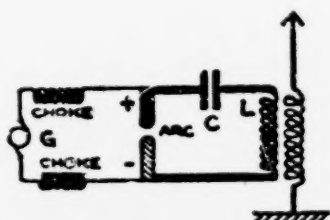


FIG. 180.—Duddell arc.

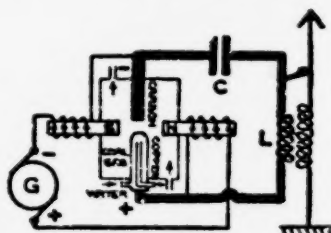


FIG. 181.—Poulsen arc.

denser, and the arc regains its original condition. When the current via the arc has risen to its original value, its resistance falls, and in consequence the potential across the arc falls. The condenser then begins to discharge across the arc, so reversing the previous condition.

The inductance in the shunt circuit gives this circuit inertia so that the current having started, the circuit is always carried past the stable condition and oscillations occur. The existence of the oscillation depends upon the fact that the resistance of the arc varies with the current in such a manner that the potential difference between the carbons diminishes with increasing current, and the arc behaves as though it had a negative resistance.



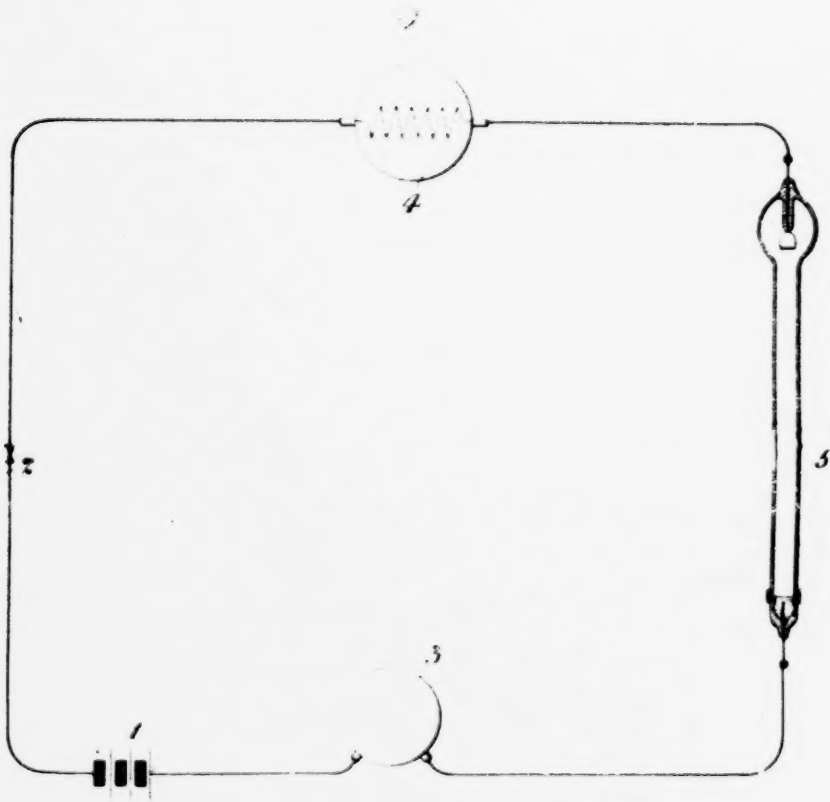
No. 781,001.

PATENTED JAN. 31, 1905.

P. C. HEWITT.

MEANS FOR AMPLIFYING ELECTRICAL VARIATIONS.

APPLICATION FILED MAY 16, 1902.



Witnesses  
 Charles H. Stock  
 Charles H. Stock

Inventor  
 Peter Cooper Hewitt  
 By his Attorney  
 Charles A. Tamm



# UNITED STATES PATENT OFFICE.

PETER COOPER HEWITT, OF NEW YORK, N. Y., ASSIGNOR, BY MESNE ASSIGNMENTS, TO COOPER HEWITT ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

## MEANS FOR AMPLIFYING ELECTRICAL VARIATIONS.

SPECIFICATION forming part of Letters Patent No. 781,001, dated January 31, 1905.

Application filed May 16, 1902. Serial No. 107,804.

*To all whom it may concern:*

Be it known that I, PETER COOPER HEWITT, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Means for Amplifying Electrical Variations, of which the following is a specification.

In certain patents granted to me September 17, 1901, attention is called to the fact that the resistance of an inclosed vapor or gas carrying current in an electric circuit varies inversely with the current carried by the vapor. Accordingly if a varying potential be applied to an apparatus of the general character described in the patents referred to a variation of current will take place in the inclosed gas or vapor, and this variation of current will affect the entire circuit in which the apparatus is included, and if the circuit is so arranged that the gas or vapor apparatus shall represent a considerable portion of the total resistance of the circuit the variations of current thus caused in the conducting gas or vapor will cause comparatively large variations in the entire circuit.

It is customary to operate electric circuits for various purposes by causing variations of potential in the circuit, such variations being utilized to influence appropriate receiving apparatus. In the present invention I avail myself of the peculiar features of electrical resistance in a gas or vapor conductor to vary or magnify the effects produced by potential variations in a circuit. By virtue of the described characteristics of gas or vapor conductors it is possible, for instance, to translate variations of potential in a circuit into variations of current or quantity, and inasmuch as the conducting gas or vapor responds practically instantaneously to the applied variations of potential, currents of any practical rapidity or frequency can be made to undergo the described transformation and produce their effects upon a suitable receiving apparatus. As the practical result of an increase of applied potential is an increased flow of current, the original electrical im-

pulses in the circuit may produce magnified effects as compared with those which the same impulses would produce if applied directly to the receivers.

The drawing herewith is a diagram of a typical circuit embodying my invention.

In the drawing, 1 is a suitable source of current supplying a circuit 2. Included in the circuit are a transmitting or potential-changing apparatus 3 and a receiving apparatus 4. The transmitting apparatus may be a telegraph-relay, a telephone-transmitter, or any other device adapted to vary the potential of the current in the circuit 2. The receiving apparatus 4 may be any suitable receiver adapted to respond to variations of current in the line.

A circuit made up as described is common enough in the electrical arts. The improvement forming the subject of the present application consists in causing the described circuit to be affected by the peculiar action of an inclosed gas or vapor apparatus, (shown at 5.) This apparatus may be such an apparatus as described in my patents above referred to as a "gas" or "vapor" electric lamp, or it may be an apparatus generally similar to such a lamp, but having no light giving quality by reason of being specially adapted to the purposes of this invention without regard to the matter of light. For this purpose the device may be made with a comparatively short gas or vapor path and having such cross-section that with the current normally traversing it the vapor or gas may become but faintly luminous. The resistance of the circuit outside the device 5 is practically constant except for the slight variations introduced through the instrumentality of the potential-changing apparatus 3. As the resistance of the device 5 varies substantially inversely with the quantity of the current flowing, or, to put it another way, requires a definite voltage to pass a definite current therethrough any diminution, for instance, of the potential applied to its terminals by reason of an increase of resistance on the part of the device 5 will result in not only the diminution of flow of current due to the

increased resistance of the device 3, but also to an additional diminution due to the change brought about in the device 5 by the decreased current resulting from the decreased potential at the terminals of the device 5. Likewise an increase of potential at the terminals of the device 5, due to a change of resistance in the outside circuit, will cause an increase of current-flow therethrough greatly in excess of the change due to the change of resistance in the other portions of the circuit. In other words, the changes of resistance in other portions of the circuit than the device 5 bring about such variations of conditions in the device 5 as to augment the variations of current-flow ~~through~~ the entire circuit. It should be borne in mind, however, that the resistance of the other portions of the circuit than the device 5 serves in a measure as a balancing resistance for the device 5; otherwise a decrease of resistance in the external circuit might result in a continuing unchecked decrease of the total resistance of the circuit including the device 5. The device 5 itself, however, has in a measure a self-corrective tendency within certain limits, due to internal variations of resistance resulting from changes in its temperature. The temperature of the device 5 must be taken into consideration when measuring the device for ohmic resistance, as its ohmic resistance varies with the temperature which is brought about by variations in the flow of current and also by the surrounding conditions. The method of controlling these is set forth in the patents hereinbefore referred to. The variations in the amount of current through which the device 5 may be made to operate may be made quite wide by constructing it with the required heat-radiating capacity. It will now be understood that the receiving apparatus 4 will be affected by a comparatively large current and will respond with greater certainty and effectiveness than it otherwise would. The same amplification of the effects of potential changes in the circuit

takes place whatever be the degree of potential increase or variation.

When the resistance of the element 5 is made a considerable portion of the total resistance of the circuit, the effect of the changes of resistance in the element named will be very marked, especially when the source of supply is great.

By reason of the gaseous condition of the conducting medium employed the gas or vapor apparatus responds instantly to potential changes in the current without essential loss of energy. In this respect it differs from other materials or substances, because in such other materials or substances work has to be done in the process of reducing the resistance whereby a loss of energy is caused and the time element becomes a considerable factor, while in my apparatus the amount of material so affected is so small that the energy required to produce the result may be practically neglected.

Means for starting the flow of current through the apparatus are set forth in the patents hereinbefore referred to.

I claim as my invention

1. The combination in an electric circuit, of a source of potential variation, a receiving apparatus adapted to translate the variations caused by the source, and an inclosed gas or vapor conducting medium.

2. The combination in an electric circuit, of a source of potential variations, a receiver adapted to respond to changes of current in the circuit, and a quickly-responding inclosed gas or vapor conducting medium whose resistance decreases with increments of temperature.

Signed at New York, in the county of New York and State of New York, this 9th day of May, A. D. 1902.

PETER COOPER HEWITT.

Witnesses:

WM. H. CAPEL

GEORGE H. STOCKBRIDGE.

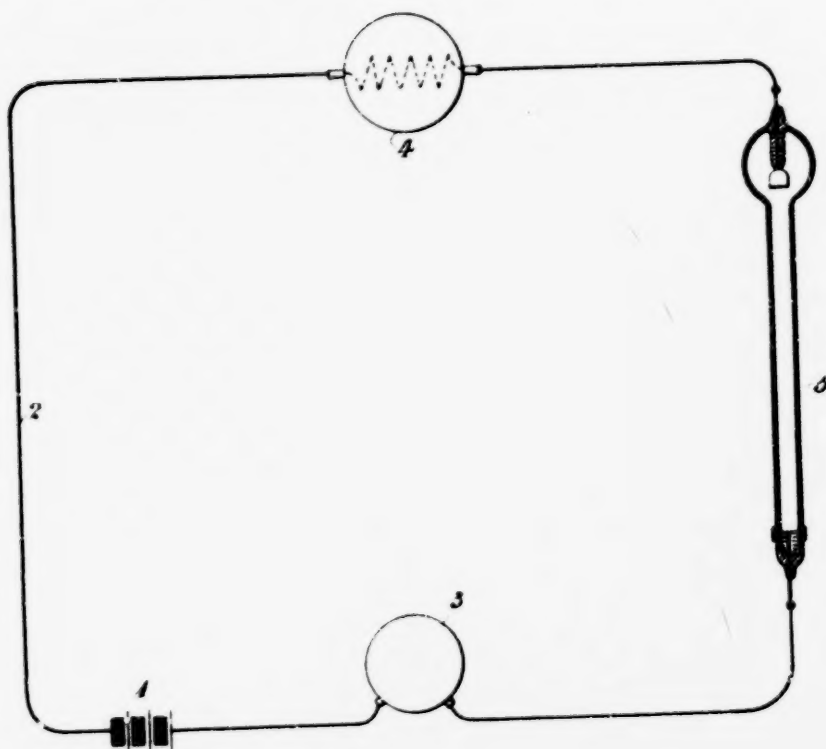
No. 781,002.

PATENTED JAN. 31, 1905.

P. C. HEWITT.

METHOD OF AMPLIFYING ELECTRICAL VARIATIONS.

APPLICATION FILED MAY 16, 1902.



Witnesses  
*Frank A. Ober*  
*George H. Docke*

Inventor  
*Peter Cooper Hewitt*  
 By *his* Attorney:  
*Charles A. Perry*

0021

# UNITED STATES PATENT OFFICE.

PETER COOPER HEWITT, OF NEW YORK, N. Y., ASSIGNOR, BY MESNE ASSIGNMENTS, TO COOPER HEWITT ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

## METHOD OF AMPLIFYING ELECTRICAL VARIATIONS.

SPECIFICATION forming part of Letters Patent No. 781,002, dated January 31, 1905.

Application filed May 16, 1902. Serial No. 107,806.

*To all whom it may concern:*

Be it known that I, PETER COOPER HEWITT, a citizen of the United States, and a resident of New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Methods of Amplifying Electrical Variations, of which the following is a specification.

In certain patents granted to me September 17, 1901, notably in the patents numbered 682,695, 682,696, and 682,697, attention is called to the fact that the resistance of an inclosed vapor or gas carrying current in an electric circuit varies inversely with the current carried by the vapor. Accordingly if a varying potential be applied to an apparatus of the general character described in the patents referred to a variation of current will take place in the inclosed gas or vapor, and this variation of current will affect the entire circuit in which the apparatus is included, and if the circuit is so arranged that the gas or vapor apparatus shall represent a considerable portion of the total resistance of the circuit the variations of current thus caused in the conducting gas or vapor will cause comparatively large variations in the entire circuit.

It is customary to operate electric circuits for various purposes by causing variations of potential in the circuit, such variations being utilized to influence appropriate receiving apparatus. In the present invention I avail myself of the peculiar features of electrical resistance of a gas or vapor conductor to vary or magnify the effects produced by potential variations in a circuit.

By virtue of the described characteristics of gas or vapor conductors it is impossible, for instance, to translate variations of potential in a circuit into variations of current or quantity, and inasmuch as the conducting gas or vapor responds practically instantaneously to the applied variations of potential currents of any practical rapidity or frequency can be made to undergo the described transformation and produce their effects upon a suitable receiving apparatus. As the practical result of

an increase of applied potential is an increased flow of current, the original electrical impulses in the circuit may produce magnified effects as compared with those which the same impulses would produce if applied directly to the receivers.

The drawing herewith is a diagram of a typical circuit embodying my invention.

In the drawing, 1 is a suitable source of current supplying a circuit 2. Included in the circuit are a transmitting or potential changing apparatus 3 and a receiving apparatus 4. The transmitting apparatus may be a telegraph-relay, a telephone-transmitter, or any other device adapted to vary the potential of the current in the circuit 2. The receiving apparatus 4 may be any suitable receiver adapted to respond to variations of current in the line.

A circuit made up as described is common enough in the electrical arts.

The improvement forming the subject of the present application consists in causing the described circuit to be affected by the peculiar action of an inclosed gas or vapor apparatus, (shown at 5.) This apparatus may be such an apparatus as described in my patents above referred to as a "gas" or "vapor" electric lamp, or it may be an apparatus generally similar to such a lamp, but having no light-giving quality by reason of being specially adapted to the purposes of this invention without regard to the matter of light. For this purpose the device may be made with a comparatively short gas or vapor path and having such cross-section that with the current normally traversing it the vapor or gas may become but faintly luminous. The resistance of the circuit outside the device 5 is practically constant except for the slight variations introduced through the instrumentality of the potential-changing apparatus 3. As the resistance of the device 5 varies substantially inversely with the quantity of the current flowing, or, to put it another way, requires a definite voltage to pass a definite current there-through, any diminution, for instance, of the potential applied to its terminals by reason of an increase of resistance on the part of the de-

vice 3 will result in not only the diminution of flow of current due to the increased resistance of the device 3, but also to an additional diminution due to the change brought about in the device 5 by the decreased current resulting from the decreased potential at the terminals of the device 5. Likewise an increase of potential at the terminals of the device 5 due to a change of resistance in the outside circuit will cause an increase of current-flow there-through greatly in excess of the change due to the change of resistance in the other portions of the circuit. In other words, the changes of resistance in other portions of the circuit than the device 5 bring about such variations of conditions in the device 5 as to augment the variations of current-flow through the entire circuit. It should be borne in mind, however, that the resistance of the other portions of the circuit than the device 5 serves in a measure as a balancing resistance for the device 5. Otherwise a decrease of resistance in the external circuit might result in a continuing unchecked decrease of the total resistance of the circuit including the device 5. The device 5 itself, however, has in a measure a self-corrective tendency within certain limits due to internal variations of resistance resulting from changes in its temperature. The temperature of the device 5 must be taken into consideration when measuring the device for ohmic resistance, as its ohmic resistance varies with the temperature which is brought about by variations in the flow of current and also by the surrounding conditions. The method of controlling these is set forth in the patents hereinbefore referred to. The variations in the amount of current through which the device 5 may be made to operate may be made quite wide by constructing it with the required heat-radiating capacity.

It will now be understood that the receiving apparatus 4 will be affected by a comparatively large current and will respond with greater certainty and effectiveness than it otherwise would.

The same amplification of the effects of potential changes in the circuit takes place whatever be the degree of potential increase or variation.

When the resistance of the element 5 is made a considerable portion of the total resistance of the circuit, the effect of the changes of resistance in the element named will be

very marked, especially when the source of supply is great.

By reason of the gaseous condition of the conducting medium employed the gas or vapor apparatus responds instantly to potential changes in the current without essential loss of energy. In this respect it differs from other materials or substances, because in such other materials or substances work has to be done in the process of reducing the resistance, whereby a loss of energy is caused and the time element becomes a considerable factor, while in my apparatus the amount of material so affected is so small that the energy required to produce the result may be practically neglected.

Means for starting the flow of current through the apparatus are set forth in the patents hereinbefore referred to.

I claim as my invention—

1. The method of amplifying potential variations caused in an electric circuit, which consists in applying the said variations to a quickly-responding medium in the circuit, thereby causing a change in current-flow through such medium, and by such change of current-flow producing in such medium a change of specific resistance resulting in a still further change in current-flow through the circuit.

2. The method of amplifying energy variations caused in an electric circuit of which an inclosed gas or vapor forms part, and of translating the effects of such amplified variations, which consists in affecting the conducting gas or vapor by variations of current, transforming such variations of current into variations of resistance, and applying such currents to a suitable translating device.

3. The method of amplifying energy variations caused in an electric circuit including an inclosed conducting gas or vapor and electrodes therefor, which consists in affecting the conducting gas or vapor by variations of current, and thereby transforming such variations into corresponding amplified variations of current.

Signed at New York, in the county of New York and State of New York, this 9th day of May, A. D. 1902.

PETER COOPER HEWITT.

Witnesses:

WM. H. CAPEL,

GEORGE H. STOCKBRIDGE.

[fol. 2914]

## DEFENDANT'S EXHIBIT S

*The Principles Underlying Radio Communication*

Radio Pamphlet No. 40, December 10, 1918, Signal Corps,  
U. S. Army. Washington, Government Printing Office,  
1919

to be used for large distances. In this factor,  $\lambda$  enters in such a way as to make the received current less when the wave length is short than when it is long. Hence, in general, we conclude that to get the greatest possible received current, we should use short waves for short distances and long waves for long distances.

It may be seen from the formulae that, for simple antennae, the received current (for a given wave length, sending current, receiver resistance, and distance apart) is greater, the greater the heights of the antennae. In the case of closed-coil aerials under the same conditions, the received current is greater the larger the areas and the number of turns of the coils. For the dimensions actually used, antennae are much more effective radiators and receivers than closed coils. In order to secure the same radiation or received current with a closed coil as with an antenna, other conditions being the same, its dimensions must be made nearly as great as the antenna height. However, it is often possible to put more current into a transmitting coil than into the corresponding antenna, and also the resistance of a receiving coil is usually smaller than that of the corresponding receiving antenna. Hence the closed coil can be a smaller structure than the antenna.

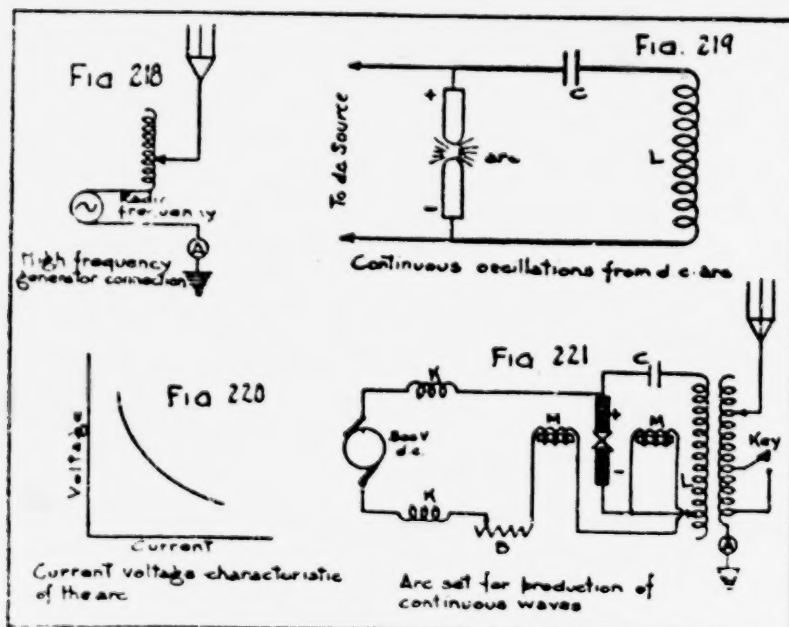
The closed coil has some other advantages. For a given power input in the transmitter, the closed coil aerial is not at quite such a disadvantage with the ordinary antenna as the formulae show, because a larger fraction of the radiation is sent out in the direction desired. As a receiver, the closed coil has the very great advantage that the direction of the waves it receives can be determined. These points are discussed further in the next chapter.

## E. Device for Radiating and Receiving Waves

137. *Description of the Antenna.*—The antenna is used in radio communication for two purposes, (1) to radiate elec-

tric waves, and (2) to receive or detect electric waves which come to it. An antenna consists essentially of one or more wires, suspended at some elevation above the earth. When electric waves reach an antenna, they set up an alternating emf. between the wires and the ground, and the longer and higher the wires, the greater the emf. produced. As a result of this emf., an alternating current will flow in the antenna wires. The energy of the current is absorbed from the passing wave, just as some of the energy of a water wave is used up in causing vibrations in a slender reed which stands in its way.

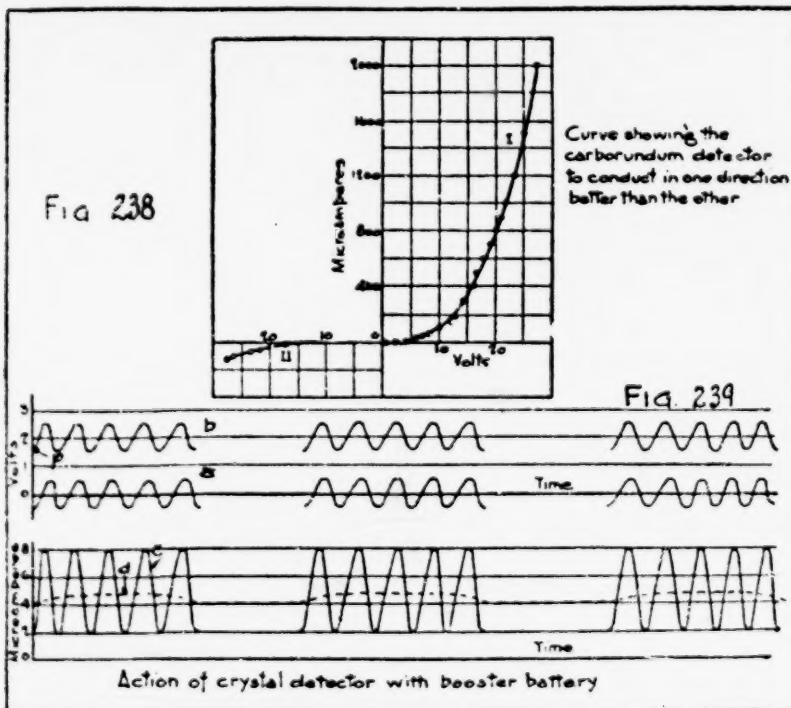
[fol. 2915] frequency can be used. See Section 95. This is connected directly or inductively to the antenna and ground. See Fig. 218. This constitutes the simplest possible connection for producing continuous waves. However, to obtain a wave length as short as 1500 meters, the frequency of the alternating current must be as high as 200,000 cycles per second. The generator speed required to produce this frequency is so high that a special type of construction is needed for such a machine. It is also necessary to have apparatus for keeping the speed constant, so that the wave



length will not change (since  $f_{\lambda m} = 300,000,000$ ). This method is not available for generating very short waves; for these, the oscillating vacuum tube is used. See Section 198.

174. *Arc Sets*.—A much used method for producing undamped waves of rather great wave length is by means of a d. c. arc operated on about 500 volts. It has been discovered that an electric arc between proper electrodes shunted by an inductance coil and a condenser will produce undamped oscillations through the shunt circuit. The connection is shown in Fig. 219. The operation is as follows.

[fol. 2916] Fig. 238 shows a current-voltage characteristic curve for carborundum in contact with a metal. The current flows much more readily in one direction than in the other under equal but opposite emf's. For example, under a constant impressed emf. of 10 volts in one direction a current of 100 microamp. is obtained, while with the voltage reversed the current is only 1 microamp. This illustrates the property of "unilateral conductivity," or rectification. Furthermore, as regards the second property, when the



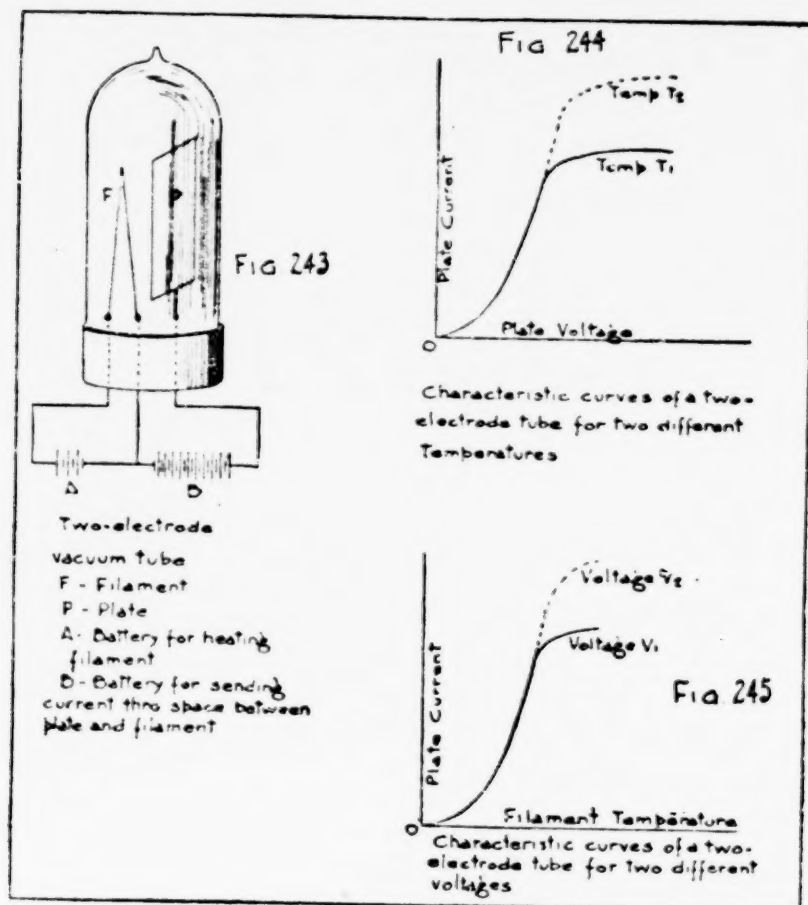
voltage is applied in the direction giving the larger current, the conductivity (ratio of current to voltage) increases as

the voltage increases. This is shown by the right hand portion of the figure. The characteristic curve of any ordinary metallic conductor would be a straight line.

*Booster Battery.*—In order to make use of the second property namely the bending of the current-voltage characteristic, a local or "booster" battery is inserted in series with the crystal. Using the battery makes the crystal operate at a voltage which corresponds with the sharpest bend of the curve, so that a slight increase of volt-

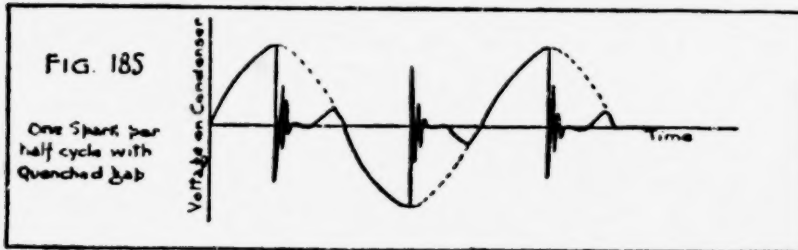
[fol. 2917] the vacuum is very complete. If there is more than the merest trace of gas remaining in the tube, the operation is more complicated, and a larger current will usually flow with the same applied voltage. This happens in the following manner.

In a rarefied gas, some of the electrons present are constituent parts of atoms and some are free. These free



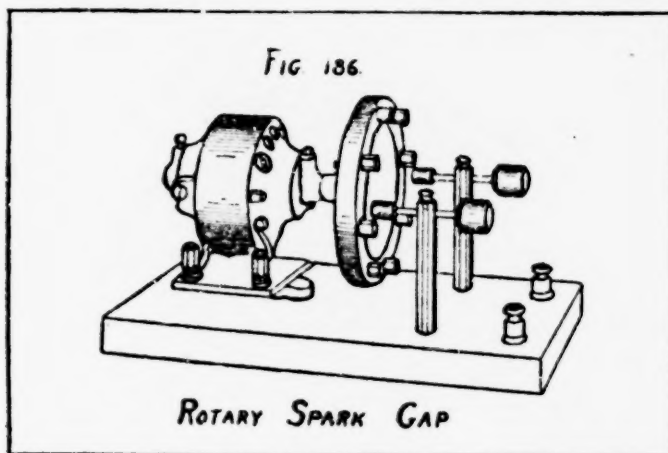
electrons move about with great velocity, and if one of them strikes an atom, it may dislodge another electron from the atom. Under the action of the emf. between plate and filament the newly freed electron will acquire velocity in one direction (that of the colliding electron) and the——

[fol. 2918] This regular occurrence of the discharges gives smooth and efficient operation, and a pure musical tone. The synchronizing is made possible by attaching the rotating element of the spark gap to the shaft of the generator



which charges the condenser. A rotary gap not so timed is called "non-synchronous."

Attempts to produce a high pitch from a 60-cycle source by a synchronous gap giving, say, exactly 6 sparks per half cycle, have not given satisfaction, because the applied voltage is not the same at the time of the different sparks, and



while the note is of high pitch, it is not musical. It has been found better to use a non-synchronous gap in such a case, producing a large number of sparks per second and letting them occur wherever they may happen——

*Principles Underlying Radio Communication, 1922*

175. *The Characteristics of the Direct-Current Electric Arc.*—If between two pieces of conducting material, such as two carbon rods, separated in air by a short distance, there is applied a considerable d.c. voltage, an arc will be formed between the carbon electrodes and will continue if a sufficient voltage is maintained. The voltage required to maintain the arc will be much less than that required to start the arc cold, and, in fact, an arc is not usually started with the electrodes separated. If we study the behavior of such an arc and measure the current corresponding to various d.c. voltages maintained at the terminals of an arc already formed, we will obtain a curve for voltage plotted against current like that shown in Fig. 223. This curve shows that as the applied voltage is increased the current through the arc decreases. The corresponding characteristic curve of an ordinary ohmic resistance would be a straight line sloping upward to the right from the origin. This behavior of the arc, exactly opposite to what occurs when the voltage applied to an ordinary conductor is increased, is described by saying that the arc has a "falling characteristic," or that it is a variable resistance, which increases as the applied voltage increases. It is this "falling characteristic" of the arc that makes possible its use as a generator of undamped oscillations.

When the arc is used to generate undamped oscillations the current which flows at any instant between the arc electrodes is the resultant of the steady current supplied by the d.c. generator and the current in the condenser shunt circuit, as described in the next section. In the first two cases described in the next section, which can properly be considered to be arc discharges, the current between the electrodes always flows in the same direction, but may vary in magnitude.

The statement is sometimes made that an arc is a "negative resistance"; this statement can not be considered correct. The current in an arc passes from the electrode of higher voltage to

[fol. 2920] The production of this effect is, however, subject to certain conditions. The arc A must be formed by the electromotive force of a secondary battery or other steady generator, and a resistance, R (see Fig. 81), must be placed in series with it. The inductive resistance L placed a shunt to the arc must be a low resistance—generally speaking, something less than 1 ohm. The condenser C employed should be one suitable for high potential, as although the impressed electromotive force on it is only 50 volts, the action of resonance (see Chap.

III) creates a potential difference between its plates, which at moments rises to several hundred volts, and hence a thin paper condenser may break down.

One explanation put forward as an explanation of this effect on its dis-

covery was that it essentially depends upon the existence of a *negative resistance* in the arc, and that the frequency which can be obtained is limited by the arc itself. We shall present the outlines of this theory first, as proposed by Mr. Duddell and supported by some others.

Suppose a small instantaneous change  $dV$ , is made in the potential difference of the electrodes, whether carbon or metal, between which the arc is formed, and let the corresponding small change in the current through the arc be denoted by  $dA$ . Also let the resistance of the inductance in series with the condenser be represented by  $r$ . The theory advocated by Mr. Duddell is that the conditions for the production of high frequency alternating currents

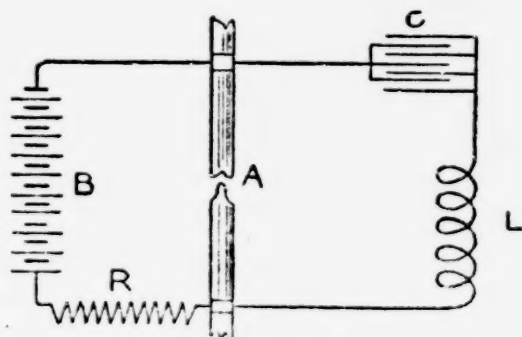


FIG. 81.—Arrangements for producing Duddell's Musical Arc. B, battery; R, resistance; A, carbon arc; C, condenser; L, inductance.

. . . . .

It has been shown by the author that even then the oscillations are not quite continuous.<sup>1</sup> The oscillating arc tends to break up into a series of intermittent discharges, and it is somewhat difficult to obtain absolutely unbroken undamped oscillations. Some interesting investigations were carried out in the author's laboratory in 1907 by Mr. W. L. Upson, on the characteristic curves of electric arcs between various electrodes and in different gases.<sup>2</sup> These experiments showed that for an arc taken between a carbon (negative) and a water cooled copper (positive) electrode the characteristic curve is much steeper at and about the same arc current, than for the carbon-carbon arc in air (see Fig. 86). Hence it is clear that one element in Poulsen's discovery is [fol. 2921] the effect of hydrogen or hydrocarbon vapour in steepening the characteristic curve of the direct current arc. The reason for this has not yet been fully explained.

Poulsen immediately applied the above method for producing undamped electric oscillations in radiotelegraphy, with the cooperation of P. O. Pedersen.<sup>3</sup>

<sup>1</sup> See J. A. Fleming, "On the Poulsen Arc as a Means of generating Undamped Oscillations," *Phil. Mag.*, August, 1907; also *Proc. Phys. Soc., Lond.*, vol. 20, 1907; also "Recent Advances in Electric Wave Telegraphy," a discourse at the Royal Institution. See *The Electrician*, May 31, June 7, 14, 21, 1907.

<sup>2</sup> See W. L. Upson, "Observations on the Electric Arc," *Proc. Phys. Soc., Lond.*, vol. 20, 1907, or *Phil. Mag.*, July, 1907. Also J. A. Fleming, "Some Observations on the Poulsen Arc as a Means of obtaining Continuous Electric Oscillations," *Phil. Mag.*, August, 1907, series vi, vol. 14, p. 254.

<sup>3</sup> See V. Poulsen, "A Method for producing Undamped Electric Oscillations and its Employment in Wireless Telegraphy," *The Electrician*, vol. 58, p. 166, 1906. In this article a number of diagrams are given showing the type of receiving circuit used.

We shall return again, in Chap. VIII, on radiotelegraphic stations, to the consideration of the practical use of Poulsen's discovery and apparatus in wireless telegraphy and telephony.

Meanwhile the reader's attention may be drawn to one or two other points in connection with the production of electric oscillations by the arc.

Much light has been thrown on the nature of the phenomenon by the careful researches of Professor H. Th. Simon.<sup>4</sup> He has studied by means of the oscillograph and Braun vacuum tube, the form of

#### DEFENDANT'S EXHIBIT V *Wireless Telegraphy and Telephony*

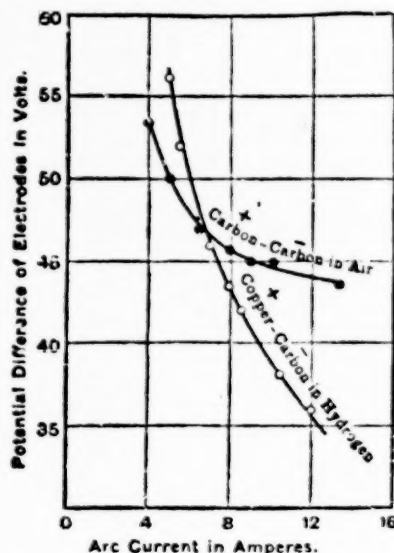


FIG. 86.—Diagram showing Results of Upson's Experiments on Characteristic Curves of Arcs.

A Handbook of Formulae, Data and Information. By W. H. Eccles, D.Sc., A.R.C.S., M.I.E.E., Professor of Applied Physics and Electrical Engineering at the City and Guilds of London Technical College, Finsbury. Honorary Secretary of the Physical Society of London and of the British Association Committee for Radiotelegraphic Investigations. Second Edition, Revised and Enlarged, 1918

(a) The maximum value of the oscillatory current may be so much less than the steady current that the arc is not extinguished. This is the case of the musical arc first described fully by Duddell.

(b) The discharge current from the condenser may be so large as to extinguish the arc at an instant near the maximum of the oscillatory current. This includes the usual case of the Poulsen arc.

<sup>4</sup> See H. T. Simon, "The Dynamics and Hysteresis of the Electric Arc," *Phys. Zeitschrift*, vol. 6, p. 297, 1905, or *Science Abstracts*, vol. 8x, abs. 1465; also "Theory of the Singing Arc," *Phys. Zeitschrift*, vol. 7, p. 433, 1906, or *Science Abstracts*, vol. 9x, abs. 1423.

(c) The oscillatory current may, after extinguishing the arc, kindle it in the direction opposite to the steady current. [fol. 2922] This is exemplified by the quenched spark with the "ordinary" spark as an extreme case. They have been discussed in the preceding pages.

*CASE a.—Condenser Current Less than Arc Current.—* The first type of arc generator, which gives nearly pure sine oscillations of feeble intensity, has had no application. The greatest rates of conversion of direct current energy into oscillatory energy are reached within acoustic limits of frequency.

The ability of an arc to sustain oscillations in a shunt circuit depends on the fact that in the circumstances in which it is used, an increase of current through the arc involves a decrease of the voltage at its terminals, and vice versa. The curve connecting  $i$  and  $v$  with values of  $i$  as abscissae is called the "characteristic" curve of the arc; it has a negative gradient. Suppose the condenser-inductance circuit applied suddenly as shunt to an arc supplied with a constant current  $i_0$ . The condenser begins to charge, robs

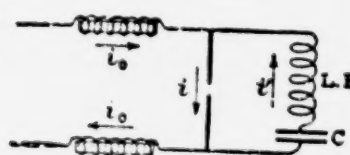


FIG. 129.

the arc of current, the arc voltage therefore rises, and the condenser charges still further. A limit to the voltage is reached when the condenser current stops increasing, for then the steady current through the arc starts increasing,

the voltage falls and the condenser begins to discharge more or less in the time of oscillation determined by  $L$  and  $C$ . The condenser discharge current now adds to the steady current through the arc, makes the arc terminal voltage lower than the normal, and encourages the motion of the electricity, which goes on till the condenser is fully charged in sign opposite to the last occasion. The process plainly goes on indefinitely. The arc thus acts somewhat like the slide valve of a single-acting steam engine, since it automatically admits electricity at a pressure above normal into the capacity and withdraws it at a lower pressure than normal, work being done on each occasion. In Fig. 130 let  $PX$  represent the normal voltage,  $ON$  the corresponding current, of an arc with a falling characteristic. Then  $QM$  represents the condenser current and  $QN$  the voltage of the condenser terminals at a certain instant during the

oscillatory charging, and  $M'$  refers to an instant during discharge. Assuming that the oscillations follow a sine law, and that they are of the natural period of the circuit, then since  $v$  and  $i$  are in phase the work done per second in the shunt-circuit is  $\frac{1}{2}IV$  where  $I$  is the amplitude of the current,  $V$  of the voltage, of the shunt-circuit. This work may be regarded as all spent in a resistance  $R$  in the circuit, or partly in a coupled circuit, and thus

$$\begin{aligned}\frac{1}{2}IV &= \frac{1}{2}RI^2 \\ R &= V/I,\end{aligned}$$

that is,

[fol. 2923] If  $R$  exceeds this value the oscillation will not be sustained. Thus, the average negative gradient, which is  $V/I$ , or  $QQ' \div (MQ + Q'M')$ , must not be less than  $R$ . For infinitesimal oscillations this may be written

$$R < -\frac{dv}{di},$$

which is sometimes called Kaufmann's condition.

H. T. Simon first made clear that the characteristic curve of Fig. 130 is not followed exactly during rapid oscillations: during reduction of current a lower curve during augmentation of current a higher curve, is followed. (See Case *b*.) Being a time effect, this has no analogy with hysteresis, though sometimes given that name in error. This "dynamic characteristic" for *a* type oscillations is indicated in Fig. 131.

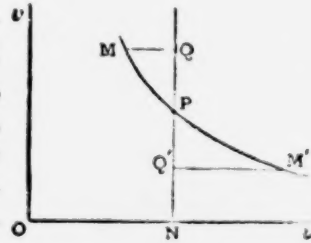


FIG. 130.

W. Duddell has given the following details of a musical arc: Carbons solid, Conradty, 9 mm. diameter, arc length 1.5 mm., arc current 3.5 A, steady-state resistance 42  $\Omega$ , shunt inductance 5.3 mH, resistance of inductance and leads 0.41  $\Omega$  capacity of condenser 1.1 to 5.4  $\mu$  F, R.M.S. current through condenser 3 A when capacity is 5.4  $\mu$  F, voltage of battery 50 V.

*CASE b, —Condenser and Arc Currents Nearly Equal.*—The second type of arc generator, the Poulsen arc, gives very energetic oscillations at frequencies up to two or three millions per second, and is used in the Poulsen system of wireless telegraphy (see "Systems"). In order to make the



FIG. 131. Dynamic characteristic of a-type oscillations.

characteristic steep and allow of the use of high voltages, it is advantageous to form the arc between carbon and copper electrodes, with the copper as the positive pole, in an atmosphere of hydrogenous vapour (Fig. 132). The desired periodic extinction of the arc is assisted by strongly cooling the electrodes and by forming it in a strong perpendicular magnetic field, but is governed largely by the relative magnitudes of condenser and inductance. Kiehlitz states that when the inductance is too small (the product  $LC$  being of assigned value) the arc is very sensitive to changes in the supply of voltage, the frequency of the oscillations varies

Although a great many investigators have attempted to give the rationale of the Poulsen arc, it was not until very recently that even an approximate understanding of its operation was attained. P. O. Pedersen points out that many early investigations are vitiated by the fact that the arc as set up in laboratories for investigation has usually been working under conditions different from those of the [fol. 2924] Poulsen arc as used in practice. He calls the practical size of arc the "normal Poulsen arc." Such an arc is one with at least 10 to 15 amperes direct current, and with, for example a value  $\sqrt{L/C} = 50$  ohms at wave length 1,000 m. In the normal arc the arc is extinguished and ignited every period of the oscillation, and the ratio of the effective oscillatory current to the steady feeding current is  $1/\sqrt{2} = 0.707$ . Such an arc gives maximum efficiency of conversion when the voltage across it is the least possible, and for this a definite gap and a definite magnitude of field are required, whose values depend on the constants of the circuits. The arc will maintain oscillations for adjustments of gap slightly different from the optimum and great latitude in magnetic field is possible if the normal condition has not to be maintained. According to Barkhausen, the connection between current and voltage at the arc during oscillation is as follows: The arc burns for the greater part of the oscillation at a steady voltage, while the current rises and falls when the voltage reaches a very low value the arc expires suddenly, and the voltage falls to a low negative value in common with the condenser it then rises, while the current

is still zero, to a high value, perhaps tenfold the burning value, and the arc is ignited; immediately the current is established the voltage falls to the burning value and remains practically steady while the current rises and falls in the oscillation. Barkhausen's view is that the high ignition voltage is the essential element in the efficient working of the Poulsen arc, and that the hydrogenous atmosphere and the magnetic field operate by enhancing the ignition voltage. Pedersen's experiments contradict this view as regards the normal Poulsen arc, through supporting it to some extent if the gap is much too long for normal. In the normal arc, in fact, the ignition voltage is not very high, and the efficiency of the normal arc is brought about almost entirely by the high value of the voltage rise that occurs at the *extinction* of the arc, which was disregarded by Barkhausen. This rise of voltage at extinction has been shown previously to exist in the case of the musical arc by A. Blondel using his oscillograph, and it is now shown to be of paramount importance in the radiofrequency arc by Pedersen's oscillograms obtained with Gehecke's cathode glow oscillograph. It is, no doubt, the consequence of the negative gradient of the arc characteristic.

With the correct arc gap and the correct strength of magnetic field, the oscillogram of the current through the arc is an almost complete sine-wave with small sections cut away from the troughs near the maximum negative point, and the voltage rises and falls sharply at the extinction, and also at the ignition, point without becoming negative at any time. The arc is struck on or near the edges of the electrodes, is driven outwards by the magnetic field, is extinguished at the extreme position and ignites afresh at the edges, the process being repeated with great regularity in each

[fol. 2925]

DEFENDANT'S EXHIBIT W

*The Radio Review, 1919*

Discussion on Thermionic Values. W. H. Eccles, "The Three-Electrode Thermionic Vacuum Tube and the Revolution in Wireless Telegraphy"

During the war dark hints reached the civilian that a revolution was taking place in wireless telegraphy, the

principal agent in which was reported to be an instrument called a "valve", a "lamp", or a "tube." This instrument seemed to have risen suddenly into a predominant position among all the apparatus of the wireless experimenter and operator, and appeared to be of use in every corner of his outfit. The complete name of the instrument is the three-electrode thermionic vacuum tube. It must be emphasised that it is the three-electrode valve, and not the valve with two electrodes, that has been responsible for the overthrowing of the old methods and apparatus. That it has been a veritable revolution can be seen by comparing the common practice in wireless telegraphy of 1914 with that of 1919. In 1914 practically all the most powerful transmitting stations in the world generated waves by sparks, and signals were received at nearly all stations by means of crystal detectors or magnetic detectors. The spark method of generating waves involved the use of very large antennæ for spanning great distances; and at receiving stations which wished to listen to stations

#### DEFENDANT'S EXHIBIT X

*Journal of the Institution of Electrical Engineers, including original communications on telegraphy and electrical science*

Published under the supervision of the editing committee and edited by W. G. McMillan, secretary. Vol XXX. 1900-01. London: E. and F. N. Spon, Limited, 125, Strand, W.C. New York: Spon and Chamberlain, 12, Cortlandt Street. 1901

*On rapid variations in the current through the direct-current arc*

By W. Duddell, Wh. Sc., Associate

It may be thought by some that the title of this paper is rather contradictory in that there should not be any variation in the current through a direct-current arc. I will therefore explain at once that I simply use the term "direct-current" as implying that the current is supplied by cells or by a direct-current dynamo, and not as implying that the

current is necessarily constant in value. It may also be as well to state that by *Arc* I do *not* mean *Arc Lamp*, as all the effects to be described are quite apart from those produced by regulating mechanisms.

The effect of varying the current through the direct-current arc is very slowly, so slowly in fact that the carbons have time to burn into shape corresponding to each value of the [fol. 2926] current, has been investigated by many experimenters, but it is to Mrs. Ayrton<sup>1</sup> that the honour belongs of giving a complete investigation of all that occurs when any of the variables in the direct-current arc are changed in any way. The other extreme, namely, very sudden changes in the current, has also been investigated by Mrs. Ayrton,<sup>2</sup> thus leaving a gap in the experimental evidence as to what occurs between very slow variations and isolated sudden changes in the current.

The present paper is an attempt partly to fill this gap by giving an account of what occurs when the current is periodically varied more or less rapidly over a range which is very small compared with the mean value of the direct current.

The current through a direct-current arc supplied with power from any circuit may vary either owing to changes taking place in the circuit, such as variations in E.M.F. or resistance, or owing to effects in the arc itself, such as hissing, humming. Although any variation in the current naturally entails a corresponding change in the arc itself, it will, I think, be found convenient to classify the observed effects according to whether the primary cause of the variation is in the arc or in the circuit which supplies it.

## Part I

### Cause of the Variation of the Current in the Circuit Supplying the Arc

The effects of varying the current may be divided under four heads, viz., the effect on the P.D. between the terminals of the arc, on the light emitted, on the shape of the craters, and on the vapour column. These will be considered in order. I shall assume in all cases in Part I. that the ampli-

<sup>1</sup> *The Electrician*, vols. xxxiv., xxxv., and xxxvi.

<sup>2</sup> *The Electrician*, 1895, vol. xxxiv., pp. 471, 541.

tude of variation of the current from the mean is small, generally much less than 10 per cent, and that the arc experimented on is neither hissing nor humming.

#### Effect on the Potential Difference Produced by Variations of the Current

If the current varies very slowly, then the relation between the P.D. current and length is that given by Mrs. Ayrton's curves. Directly the rate of variation is increased so that the carbons have not time to burn into shape, corresponding with the instantaneous values of the current, the relation will be changed, and it is conceivable that *if* the rate of variation were high enough and the amplitude small enough, the conditions of the arc would in no way be changed, so that the ratio of the change in P.D. to the corresponding change in current, would be a constant and equal to the true resistance of the arc. I shall show later that this assumption, which is the basis of several experiments on the resistance of the arc, notably those by Messrs. Frith and Rodgers,<sup>3</sup> requires a much higher rate of variation of current than they employed.

[fol. 2927] One of Mrs. Ayrton's curves, contained in a letter by Prof. Ayrton to *The Electrician*,<sup>4</sup> illustrates very well how the connection between the P.D. and current depends on the rate of variation of the latter. This curve shows that the *first* effect of *suddenly increasing the current* through a cored solid arc<sup>5</sup> is to cause a *transient rise in the P.D.* between the terminals; the effect of a *slow increase of current* being, as is well known, to produce a *decrease in the P.D.* This first transient rise in the P.D. which was obtained with a cored solid arc, was also, I believe, obtained with a cored arc, but I am unaware of its having been observed for a solid arc.

Thinking that this might be due, as pointed out by Prof. Ayrton, to the extreme quickness of the phenomenon when

<sup>3</sup> *Proceedings of the Physical Society*, 1896, vol. xiv, p. 307.

<sup>4</sup> *The Electrician*, 1896, vol. xxxvii, p. 321.

<sup>5</sup> "Solid", "solid-cored", and "cored" are mean, respectively arc between two solid carbons, between one solid and cored, and between two cored carbons; the top or + electrode being always placed first.

both carbons were solid, I tried to record the transient rise in P.D. for the solid arc by means of an oscillograph, the sudden increase of the current being obtained by discharging a condenser through the arc. This experiment was successful, and a transient rise in P.D. was observed, *the P.D. and current increasing together, but only for about 1/5000 second*. At the end of this very short time the P.D. decreased with an increase of current in the ordinary way.

If it can be assumed that during this first 1/5000 second the conditions of the arc are not changed, then the solid arc has a positive resistance, contrary to the results obtained by Messrs. Frith and Rodgers, and it is at any rate evident that, had the frequency of their superimposed alternating current between 5,000  $\sim$  per sec. instead of 250  $\sim$  per sec., the sign of the resistance as obtained by them would have changed, though I do not say that even at that frequency its true value would have been obtained. In any method for measuring the resistance of the solid arc which depends on the change in the P.D. produced by a change of current, these changes must, therefore, take place in less than 1/5000 sec. in order not to allow the arc conditions to change; results to be described later indicate a still shorter time.

I will not, however, pursue this subject any further, as it would unduly extend the length of this paper to include a description of a complete series of experiments on the resistance of the arc which I have recently completed.

#### Effect on the Light Emitted Produced by Variations of the Current

It is well known that the light of the arc varies when the current is changed, though how small and rapid the variation in current may be and yet produce a perceptible change in the light does not seem to have been investigated. Professor Fleming and Mr. Petavel<sup>6</sup> and Mr. Burnie<sup>7</sup> have determined the instantaneous values of the light and current in the case of alternate-current arcs, and have found that [fol. 2928] the variation in light roughly follows the variation of the current; the maximum luminous intensity occurring about 1/1000 sec. later than the maximum current.

<sup>6</sup> *Proceedings of the Physical Society*, 1896, vol. xiv, p. 115.

<sup>7</sup> *The Electrician*, 1897, vol. xxxix, p. 849.

Herr Görges \* has also noticed that the variations in the current due to the teeth on the armature of a dynamo produced an appreciable variation in the light at the rate of 300 per second.

In order to test how rapid and how small a variation of the current from the mean could be detected in the light of the direct-current arc, I arranged an arc so that its image as seen through a central slit parallel to the carbons was projected on to a rapidly falling photographic plate, the instantaneous value of the current being recorded simultaneously on the same plate by means of an oscillograph. The small quick variations of the current through the arc were produced by passing the oscillatory discharge of a condenser in series with a self-induction through it, so that the arc current consisted of a large constant part on which was superimposed a small ripple which died away after a few oscillations.

By this method I find that in an 8 ampere solid arc a *distinct variation is produced in the light emitted by both the + crater and the vapour column when the amplitude of the variation of the current from the mean is only 3 per cent. and the frequency of these superimposed variations is as large as 4,300 ~ per sec.* At this frequency the variation in light became indistinguishable when the amplitude of the variation of the direct current was reduced to 2 per cent.

Owing to the difficulty in estimating the points of maximum density in the band on the plate which represents the light emitted in consequence of the smallness of the variation of the current and therefore of the light, I was unable to be certain whether the maximum light lags behind the maximum current; but if it does, the lag is very slight, not exceeding  $1/10000$  sec. for an 8 ampere solid arc.

It must be remembered that the above variations of light are those of the actinic rays which affect the photographic plate; the visual rays will probably vary in a similar manner, though possibly not to the same extent.

#### Effect on the Craters Produced by Variations of the Current

Mrs. Ayrton tells me that she noticed that the variations in the current used by Messrs. Frith and Rodgers, who superimposed an alternating current of 0.5 to 1.0 ampere

\* *Electrotechnische Zeitschrift*, 1895, vol. xvi, p. 548.

R.M.S. value, at frequency of 100  $\sim$  per sec. on a 10-ampere direct-current arc, so altered the shape of the ends of the carbons that she could easily distinguish them from normal carbons formed without any variations in the current. I find that if the superimposed alternating current be reduced to 0.1 ampere under the same conditions, the ends of the carbons appear unaffected.

[fol. 2929] Effect on the Vapour Column Produced by  
Variations of the Current  
Sounds

Corresponding with each value of the current through the arc there is probably a definite cross-section of the vapour column, so that if the current varies rapidly through an arc of fixed length, the volume of the vapour will also vary and sound-waves will be given out. This, I believe, is the generally accepted explanation of the humming of the alternate-current arc.

In the case of the direct-current arc, sounds are also emitted even when the variations in the current are very slight. For example, the variation of current caused by the commutator segments of a direct-current dynamo passing under the brushes can be heard in the arc. This variation of the current caused by the commutator segments, even when in good condition, was found by Messrs. Frith and Rodgers<sup>9</sup> in the case of a 5 k.w. two-pole machine to vary between 2.5 and 9 per cent. of the mean current according to the position of the brushes.

Another striking example of how sensitive the arc is to small variations in the current is furnished by the fact that a Wehnelt interrupter, working an induction coil on the direct-current street mains, will cause any arc supplied by the same mains to give out the same noise as the interrupter itself, even when a considerable distance intervenes between the place where the arc is connected with the mains, and where the interrupter and coil are joined on, as observed by Herr Simon,<sup>10</sup> Mrs. Ayrton, and Mr. Jervis Smith.<sup>11</sup>

<sup>9</sup> *Proceedings of the Physical Society*, 1896, vol. xiv., p. 307.

<sup>10</sup> *Annalen der Physik und der Chemie*, 1898, vol. lxiv., p. 233.

<sup>11</sup> *The Electrician*, 1899, vol. xlv., p. 16.

It must be clearly understood that the arcs here referred to are normal silent arcs; that is, if they were supplied with a really steady current they would have been practically silent.<sup>12</sup>

(1) In order to determine what variation in the current was necessary to cause the arc to emit a clearly audible note, the current from a high-frequency alternator, kindly lent by Sir D. Salmons, was superimposed on the direct current by the method shown in Fig. 1. The current from the alternator passes through a condenser F, a dynamometer D, and the arc in series; and it is practically prevented from flowing through the cells which supply the arc by the self-induction L. The direct current is prevented from flowing through the alternator by the condenser F.

It was found by this means that a 10-ampere direct current, solid or cored arc, length 3 to 5 mm., would produce a distinct note even if as small a R.M.S. current as 1/1000 ampere, as measured by D, was superimposed on the direct current for frequencies of the added current from a few hundred up to 8,000 ~ per second. Thus a *variation of the* [fol. 2930] *order of 1 part in 10,000 from the mean current will alter the vapour column sufficiently to produce sound-waves.*

Further experiments with another alternator and R.M.S. superimposed currents of 1/20 to 1/10 ampere on a 10-

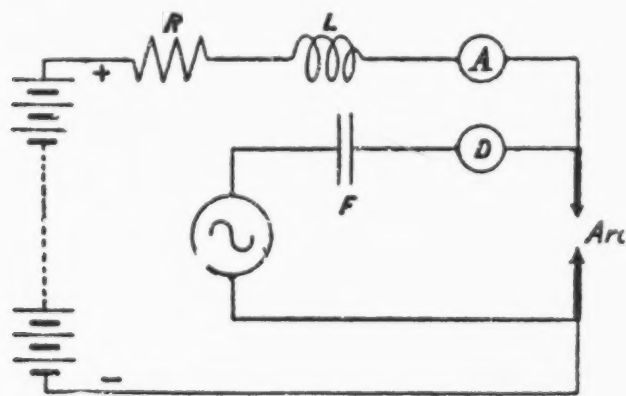


FIG. 1.

<sup>12</sup> Absolute silence is almost impossible, as the least want of homogeneity, or impurity in the electrodes, causes small spits and sounds.

ampere solid arc, proved that the sounds only became inaudible at frequencies approaching 30,000 ~ per second.

At these frequencies I am uncertain whether the arc had really ceased to give a note, as the ear fails to detect sounds of so high a pitch.

This sensibility of the arc for very small changes in its current explains the fact that not only can rapid variations

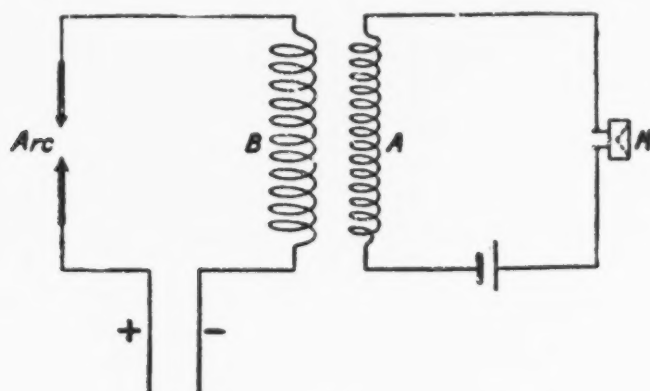


FIG. 2.

of current in any circuit supplied from the same generator as the arc be heard in the arc, but also variations of current which occur in a totally independent circuit supplied by a separate generator can be detected in the arc due to mutual induction between the two circuits.

### Arc as a Telephone Receiver

The fact that the arc is sensitive to such small variations in the current and over such a wide range of frequency, at once suggests that the direct-current arc might be used as [fol. 2931] a telephone receiver. This suggestion, which was made in a leader of *The Electrician* in 1899, had already been carried out by H. Simon<sup>13</sup> in 1898.

The method used by H. Simon for superimposing a microphone current on the main arc current is shown in Fig. 2, in which A and B are two coils having mutual induction, and M the microphone. The current through A varies when M is spoken into and induces E.M.F.'s in B, which vary the current through the arc in such a way that it reproduces sounds and even speech distinctly.

<sup>13</sup> *Annalen der Physik und der Chemie*, 1898, vol. lxiv., p. 233.

The variation of the current through the arc obtained by this method is not as large as it might be, as the E.M.F.'s induced in B have to send currents round the whole arc circuit, including any steady resistances, and also through the self-induction in the armature, if a dynamo is used, instead of only through the arc where the varying currents are actually required. I have obtained a better result by replacing the alternator of Fig. 1 with a microphone and mutual induction as shown in Fig. 3. A and B are the two coils of a mutual induction, F a condenser of about two or three microfarads, and L a high self-induction, the object of the self-induction being to prevent the microphone currents flowing around the cells instead of through the arc.

With this arrangement and suitable arc conditions, to be explained later, *the arc will speak sufficiently loudly and clearly to be heard at a distance of 10 to 12 feet in a quiet room.* [Experiment.] <sup>14</sup> The sound-waves given out by the arc are, therefore, of such an intensity that when the energy is spread over a spherical surface of 20 feet diameter, the ear placed at any point can hear speech distinctly. It seems probable that if all the energy available could be collected

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<sup>14</sup> Note (added February 1st, 1901).—As I have had several inquiries from experimenters wishing to repeat this experiment, I append some data of the apparatus actually used at the meeting.

The microphone M was supplied by the National Telephone Company and intended for long distance transmission, two accumulators being used in series with it. The mutual induction A : B consisted of a solenoid 30 cms. long wound with about 1,200 turns of No. 18 D.S.C. wire in six sections having an iron wire core about 15 mm. diameter. Diameter of solenoid over winding = 54 mm. For the experiments 3 sections = 600 turns were used for A, and two sections = 400 turns for B.

Resistance of A = 1.52, of B = 1.53 ohms. Mutual induction  $25.3 \times 10^{-3}$  henrys. Cored carbons were used in the arc, the other data being those given above.

If a suitable mutual induction A : B is not available a self-induction may be used, by connecting the leads from the microphone and cells to the terminals of B instead of those of A, B being now simply a coil having high self-induction and low resistance.

and concentrated on the ear, very powerful sound-sensations might be produced.

The loudness of the sounds given out by the arc is increased by lengthening the arc, as this increases the volume of the vapour column which emits the sounds. It would also seem as if increasing the main current which increases the cross-section of the arc should also be beneficial, but experimentally I have not found any appreciable gain. The best results have generally been obtained with a current of 10 to 12 amperes, carbons 11 to 13 mm., and an arc length of 20 to 30 mm.

To obtain these long lengths with ease, it is necessary to use cored carbons or some other means of introducing foreign bodies, such as salts of potassium and sodium, into the arc, for there is not much doubt that the stability of the arc [fol. 2932] between ordinary cored carbons is due to the presence of potassium silicate in the core.<sup>15</sup> (See also Appendix L.) These salts may be introduced either by soaking the carbons in their solutions, or by using them as cores.

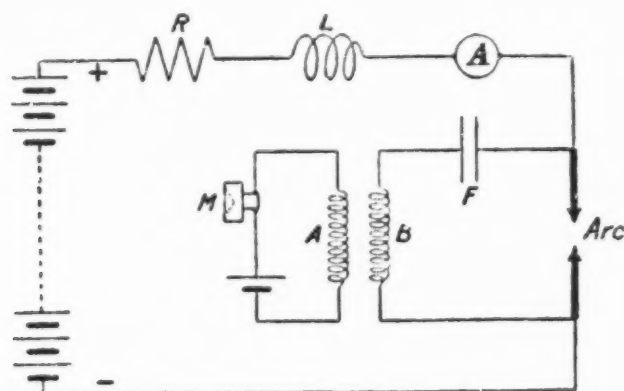


FIG. 3.

Mr. Jervis Smith has recommended the insulator glass as a core, which I find works well.

#### Arc as a Telephone Transmitter

Before leaving the subject of the use of the arc as a telephone, it will be convenient to consider its use as a telephone

<sup>15</sup> See Duddell and Marchant, *Proceedings of the Institution of electrical Engineers*, 1899, vol. xxviii., p. 66; Blondel, *International Congress of Electricity*, Paris 1900.

transmitter, though this subject strictly belongs to Part II. of this paper.

H. Simon found that if he replaced his microphone in Fig. 2 by a telephone receiver, *any sounds made near the arc were heard in the receiver*. In this case, as before, I find it preferable to modify his method by connecting the receiver in series with a condenser between the terminals of the arc, as in Fig. 4.

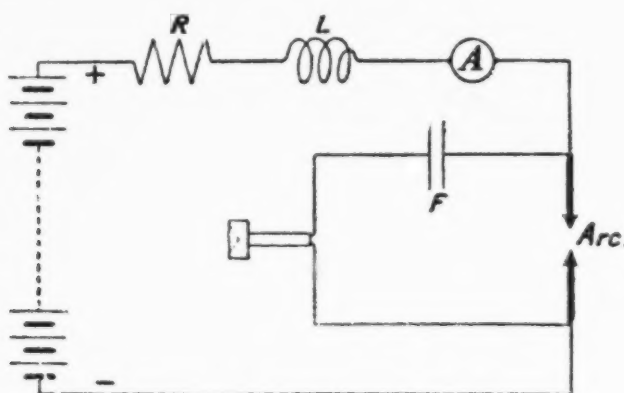


FIG. 4.

A sound-wave striking the arc may affect it in two ways, either by vibrating the arc as a whole and varying its length, [fol. 2933] or the waves of condensation and rarefaction may alter the cross section of the arc: both of these effects will tend to alter the apparent resistance of the arc, and hence vary the current through it.

The sounds obtained in the telephone receiver when using the direct-current arc as a transmitter are not generally very satisfactory, as, besides not being very loud, they are obscured by the extraneous sounds due to the small spits and hisses which occur in the arc each time the air gets to the + crater due to any slight defect in the carbons. If a common pair of carbons be used containing cracks and impurities, the noise in the receiver is sometimes unbearable, although there is no outside source of disturbance of the current through the circuit.

In all experiments on the arc as a telephone transmitter or receiver, it is essential that the current generator should be free from rapid variations, or extraneous sounds will be produced. If a dynamo has to be used, then the variations of the current produced by the commutator segments may be minimised by inserting a large self-induction in

series with the arc, as in Figs. 1, 3, and 4. This self-induction serves the double purpose of keeping extraneous variations of the current out of the arc, and of preventing the variations we desire to observe from being dissipated in the source of supply.

Thus we see that *the direct-current arc is not only extremely sensitive to small variations in its current of almost any frequency, but also that it is affected by such small changes of outside conditions as sound-waves produce.* Whether this sensibility can be turned to useful account in telegraphy or telephony remains for future experiment to decide.

## Part II

### Current Caused to Vary by the Arc

#### Humming

Mr. Trotter<sup>16</sup> discovered that the direct-current humming arc rotates, including a coma-like appearance at the + crater, and he also found that the current through the arc varied periodically, the frequency of these variations being the same as the pitch of the humming sound produced, and as the speed of rotation of the arc.

In order further to investigate the connection between the variation of the light P.D. and the current, I have recorded the P.D. and current by means of an oscillograph, the humming arc experimented on being used as the source of light to illuminate the oscillograph mirrors. The arc was so inclined that only the light from the + crater and a small part of the vapour column reached the mirrors. So that the density at any point of the lines represents the photographic intensity of the light emitted at that instant in the direction of the mirrors by the + crater and part of the vapour column, and the distance of the point from this zero line measures the P.D. or the current as the case may be.<sup>17</sup>

<sup>16</sup> *The Electrician*, 1894, vol. xxxiii., p. 298.

<sup>17</sup> In Figs. 5, 6, and 7, the centre line is not the zero line, but represents 20 amperes and 40 volts.

(Here follows 1 photolithograph, side folio 2934)

# HUMMING ARC.

CARBONS: + 11 and - 9 mm. Solid "Apostle." Mean P.D. = 50.5 volts. Mean Current = 15.2 amperes.

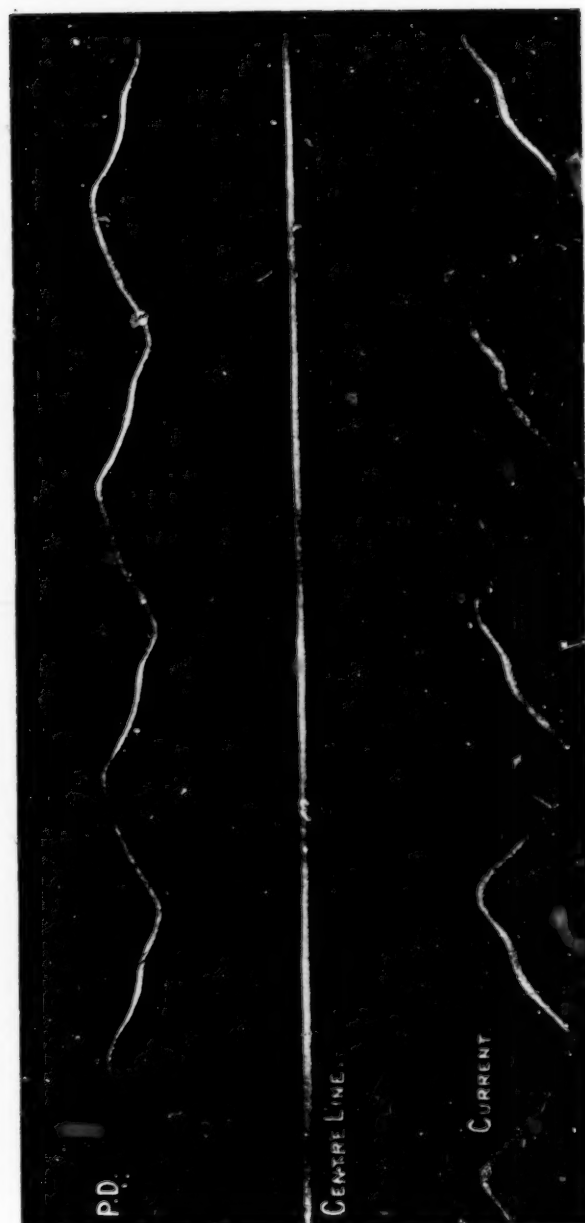


FIG. 5.

Scales: 1 mm = 0.5 volt = 0.186 ampere =  $\frac{1}{400}$  second. Centre Line = 40 volts = 20 amperes.

[fol. 2935] A typical example of the variations observed in the humming arc is given in Fig. 5, from which it will be seen that the P.D. current and light emitted in a fixed direction vary in a regular periodic manner with the same frequency.

The variation of the current, which is about 6 per cent. from the mean, is not sufficient to account for the large variation in the light emitted in the direction of the mirrors. This periodic variation of the light is most probably due to the fact that the arc rotates so that the + crater alternately either supplies light to the oscillograph mirrors, or is prevented from doing so by being on the other side of the + carbon. The periodic time of the variations of the light will, of course, be unaffected by a change in the position from which the arc is observed, but the times at which the light maxima occur relatively to the times at which the current is a maximum will depend on this position.

*Thus besides the rotation of the humming arc and the variation of the current observed by Mr. Trotter, I find that the light and P.D. vary with the same frequency, so that in the humming arc the frequencies of the rotation of the arc, and of the variations in the P.D. current, and light emitted in a given direction, are identical with the pitch of the note given out.*

. . . . .

### Musical Arc

A direct-current arc of suitable length and current, between solid carbons, will give out a musical note if it be shunted with a condenser in series with a self-induction, as

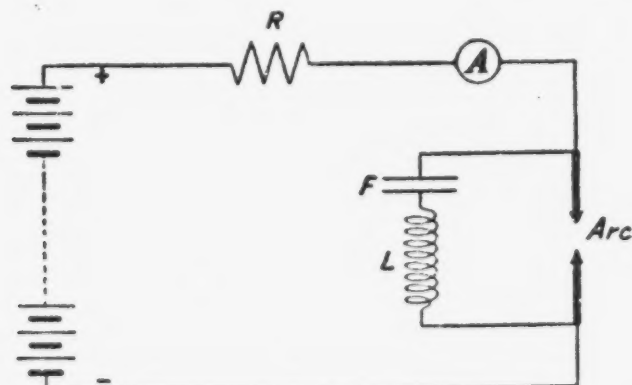


FIG. 9.

in Fig. 9, even though the source of supply of the current be perfectly constant and the arc be protected as far as possible from any outside cause of disturbance. [Experiment.]

[fol. 2936] I find that the musical note is produced by oscillatory currents flowing in the circuit composed of the condenser  $F$ , the self-induction  $L$ , and the arc, Fig. 9, and its pitch is determined by the periodic time of this circuit—that is, on the relation between the capacity, self-induction, and effective resistance of the circuit. Neglecting the resistance, which it will be shown later must be small, the periodic time of the circuit  $\tau = 2\pi\sqrt{LF}$ , and this has been found, by judging the pitch of the note by ear, to be approximately correct, so that for lecture purposes Kelvin's law can by this means be easily demonstrated. (See Appendix III.)

It must be remembered that although we have an alternate current through the condenser and self-induction, the source of supply is not an alternating one, and that *it is the arc itself which is acting as a converter and transforming a part of the direct current into alternating, the frequency of which can be varied between very wide limits by altering the self-induction and capacity.* The upper limit I find to be about 10,000  $\times$  per second, and the lower limit, if such exists, is well below 500  $\times$  per second.

It has long been known that a train of oscillations of almost any frequency can be obtained on discharging a condenser through a suitable inductive resistance, but of course these oscillations have a rapidly decreasing amplitude; and the means of supplying energy to such a circuit so as to maintain *the amplitude of the swings constant*, other than by means of a varying source of power having the same periodic time as the circuit, has been wanting. It is, therefore, necessary to inquire under what conditions it is possible for the arc to cause the source of direct current to supply the energy necessary to maintain the oscillations in the condenser circuit when once they have been started.

If the resistance in the main circuit in series with the arc is large, and if  $\delta V$  be a small instantaneous change in the P.D. between the terminals of the arc,  $\delta A$  the corresponding small change in the current through it, and  $r$  the resistance of the condenser circuit, not including the condenser; then, during the time this small change lasts, sufficient energy may be supplied to the condenser circuit to

make up for the energy dissipated there, in ohmic losses, if the following conditions are fulfilled (see Appendix II.) :—

1.  $\frac{\delta V}{\delta A}$  —, negative.
2.  $\frac{\delta V}{\delta A}$  —, numerically greater than  $r$ .

The question is, can they are fulfill these two conditions? Messrs. Frith and Rodgers<sup>18</sup> have experimentally deter-

[fol. 2937] mined the value of  $\frac{\delta V}{\delta A}$  —, which they call the resist-

ance of the arc, for various arcs, and they found that while  $\frac{\delta V}{\delta A}$

— was always + when *both* carbons were cored, it was, on  $\frac{\delta V}{\delta A}$

the contrary, always — when *both* carbons were solid; and that it was as small as —2 ohms for a 4-ampere solid arc. Now the resistance of the condenser circuit,  $r$ , external to the condenser, can easily be made less than 2 ohms, so that the arc can fulfill both the necessary conditions.

I will now describe some observations on the musical arc which tend to confirm the above conclusions.

Arcs between solid carbons for which  $\frac{\delta V}{\delta A}$  — is always nega-

tive *work well*, while those between *cored* carbons for which  $\frac{\delta V}{\delta A}$

— is positive I find *will not work* under any conditions.  $\frac{\delta V}{\delta A}$

[Experiment.]

The largest negative value of  $\frac{\delta V}{\delta A}$  — given by Messrs. Frith

and Rodgers is 2 ohms for a 4-ampere solid arc, and it is probable that it did not exceed 2.5 ohms, for the smaller cur-

<sup>18</sup> *Proceedings of the Physical Society*, 1896, vol. xiv., p. 307.

rents, viz., 3 to 3.5 amperes, which I used. According to the above conditions, 2.5 ohms should be the limiting resistance of the condenser circuit; by experiment it was found that when the resistance of this circuit was increased to 2.4 ohms the oscillations stopped and could not be re-started. [Experiment.]

It is evident that besides the resistance there are other causes, such as hysteresis, which tend to dissipate the energy in the condenser circuit and stop the arc giving its note. The hysteresis in an iron-wire core introduced into the self-induction will instantly stop the note. [Experiment.] Any complete circuit such as a ring of wire placed near the self-induction has the same effect. [Experiment.]

On several occasions before the importance of these causes of the dissipation of the energy were realised, considerable trouble was experienced in tracing the reason of the arc failing to give its note. As examples, in one case it was traced to an ammeter and in another to the tinfoil in the condenser which were acting as short-circuited secondaries to the self-induction coil, which had been placed too near them. [Experiment.]

The relation between the self-induction, capacity, and frequency can be very easily demonstrated by playing a tune on the arc by varying either the capacity or the self-induction by means of a keyboard. [Experiment.] (See Appendix III.) Another method of varying the self-induction is by separating or bringing closer together the turns of the coil, as if playing on a concertina, the relative positions of the turns determining the self-induction and the pitch of the note. The musical arc can be used as a means of comparing self-inductions or capacities by comparing the pitch of the notes produced.

The "enclosed arc" will work equally as well as the open arc, though the note given out is not so audible owing to the globe; but it can easily be made so by taking advantage of some of the telephoning effects mentioned in Part I.

The alternating current through the condenser circuit may be as large as from 3 to 5 amperes R.M.S. value, and the direct current in the main circuit also varies considerably depending on the amount of resistance in the circuit. This condenser current is sufficient to show experiments with alternating currents which do not require much power, and is very convenient in many cases for lecture purposes as the frequency, and any changes in it, are at once evident

from the pitch of the note given out by the arc. Magnetic space telegraphy can easily be demonstrated on a small scale by using the self-induction coil as the transmitting circuit. [Experiment.] Several arcs can be used in series when more power is required in the condenser circuit than can be obtained from one arc alone.

. . . . .

#### The President

The PRESIDENT: It is quite evident we have not time for much discussion, and I am sorry to say the discussion on this paper cannot be adjourned. I think, however, we ought to call upon Professor Ayrton to say how it bears upon that negative resistance of his which was so much maligned some time ago.

#### Professor Ayrton

Professor W. E. AYRTON: The paper which we have just heard read has given me exquisite pleasure: not because I have any claim to be its author, although I felt as pleased while I heard it read as if I had been the writer; nor is it merely because I feel convinced that these experiments of to-night will assist in the development of the electrical industry of to-morrow: it is rather because it so rejoices the hearts alike of professional men—yea, and of professors—to find a student who so resembles a solid carbon arc that he is ever on the alert to catch at and magnify any hint which may come from Nature or man. From Mr. Duddell's papers of two years ago, and of to-night, we learn much; among other things this second one has taught us [fol. 2939] how valuable was that research made some five years ago by Messrs. Frith and Rodgers. For what did that investigation really show us? It brought out an absolutely new fact. Supposing this is an alternating-current circuit (Fig. A), the alternator running at a given frequency and supplied with a given exciting current, the alternating current in the circuit being measured by an accurately graduated alternate-current ammeter, and that this is a wholly separate circuit—a direct-current circuit supplied by accumulators—and sending a direct current through a solid carbon arc. Then what they showed was this, that if you make a break in this alternate circuit and insert the solid carbon arc (Fig. B) without making any

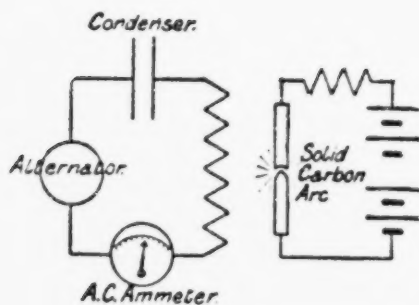


FIG. A.

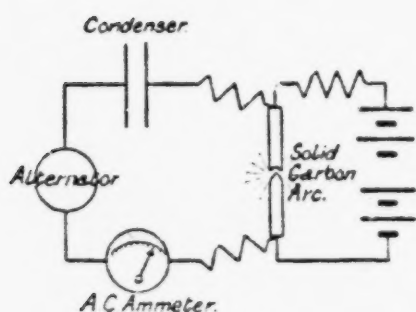


FIG. B.

change in the resistance, speed, or excitation of the alternator, etc., you increase the alternate current, not merely the current when flowing in one direction—for the condenser stops any direct current—but you increase the current in *both* directions; that is, the alternate-current ammeter reads higher after the arc has been inserted than it did before, and higher than it will if the arc be short-circuited. Now that investigation was undertaken by these gentlemen because certain theoretical considerations led me to suggest that if the method

that had been employed by various experimenters to measure the resistance of the arc—a method employed without comment or adverse criticism as long as a positive answer was obtained—was applied in a certain case to an arc a negative answer for the resistance of the arc would be found; that the method, in fact, which up to that period had been used successfully to give the resistance of the arc, and which had always given a positive value, I pointed out would give under certain conditions, a negative answer. Certain preliminary experiments having been made by Mr. Mather which confirmed my idea, a long investigation was carried out by Messrs. Frith and Rodgers. And they found that whenever the arc was formed between *solid* carbons, the ratio of an instantaneous change of P.D. to the corresponding instantaneous change of current was *negative*, whereas if the carbons were *both* *cored* it was always *positive*.

[fol. 294c] A howl of indignant criticism followed. Had Messrs. Frith and Rodgers and I lived in the Middle Ages we should undoubtedly have been burned in the solid carbon arc. But there were three distinguished investigators

who had the insight, who had the courage, not to be drawn into this net of conventional antagonism, and these were Professor Gray, then of Bangor, now Lord Kelvin's successor at Glasgow, Mr. Oliver Heaviside, and last but by no means least, the Chairman of your Dublin local section, Professor Fitzgerald, to whom we, like so many experimenters, are indebted for the many suggestions which he has made. And I, even I, ventured to suggest that progress would be more expedited, I thought, if the critics, instead of merely cavilling at the anatomy of the sugar figure on the cake, would cut it open, and see whether there were really any plums inside. It has remained, however, for Mr. Duddell to be the real Jack Horner to put in his thumb and pull out the plum, and modestly leave you and me to finish the rhyme and add "what a good boy he is."

I do not propose this evening to consider whether or not what Messrs. Frith and Rodgers measured was the true resistance of the arc, because opportunity, I hope, we shall soon have of going fully into the subject; but in justice to Messrs. Frith and Rodgers, and in virtue of the far-reaching principle that they really brought to light, I desire to emphasise what they really obtained. Mr. Duddell has taught us what was the real significance of their work. Our lost friend Professor Hopkinson, following Mr. Wilde, proved several years ago that two alternators could not be run in series. Thus, for example, if an alternator with a certain exciting current supplied to it, and driven with a steam engine, or an electric motor, or whatever it might be, were coupled mechanically to another similar alternator, driven by an independent steam engine, and speed were got up so that the two machines were going exactly in step and then were joined in series with some outside circuit, he proved to us that the moment this mechanical coupling was severed the two alternators would get out of step. So, as is well known, two alternators cannot run in series. And he might have added—if there had been the slightest necessity for him to do so—that if two alternators cannot continue running in series even if they have been started with the same frequency and exactly in step, still more impossible must it be for one alternator, driven by its own steam engine, to run in series with another independently driven when the frequency of the second is being altered within

wide limits. Nevertheless, gentlemen, that is exactly what the arc does. For in Fig. B we have one alternator running in series, with a second alternator, viz., the solid carbon arc, supplying alternating current to the circuit—because the arc transforms direct-current energy into alternate-current energy—and does it in such a way that whether the frequency of this alternator be as Messrs. Frith and Rodgers found, seven periods per second, or 70, or 170, or 250, which was the highest limit which could be obtained in my laboratory at that time, and whatever the current [fol. 2941] might be within the limits they tried, this gallant little alternator—the solid carbon arc—helps the other, and supplies current sufficiently in phase as to make the alternat  current greater when it, the arc, is inserted than when it is taken away or short-circuited.

Mr. Duddell has not only pointed out the importance of that result, the novelty of that result, but he has pointed out something even further. He has shown us that an ordinary so-called perfectly silent arc supplied with current from accumulators is, if the carbons be solid, like the mouth-piece of a flageolet or flute, not blown. The application of a shunt to that arc, consisting of a capacity in series with a self-induction, performs two operations. It starts vibrations in the arc, just as blowing a flute gives rise to vibrations of many different rates. Just as one of those rates of vibration is picked out and reinforced in the case of a flute or flageolet by the form of the resonance chamber dependent on the position of your fingers or keys, so in this musical arc the particular one of the many vibrations that is probably started which is picked out and reinforced depends on the capacity of the condenser and the value of the self-induction which is in series with it.

Already he has shown you a practical result that has followed from this. I do not mean merely those illustrations which he has given of magnetic space telegraphy, and by means of which he has shown how it has become possible to easily and experimentally demonstrate that the E. M. F. of the current induced in the distant secondary coil is proportional to the frequency of the alternating current in the primary, which will be of marked value to teachers; but beyond that he has shown us how to much improve a well-known instrument. The other day he demonstrated in my laboratory that, adding to the ordinary circuit of that very

induction-coil, joined up as usual, his little motor so as to put the condenser across the break *just after* the break was made, a spark was obtained from five to seven times as long as was obtained with the coil in the ordinary way. Even if you try to make the comparison absolutely fair, and try to arrange the very best conditions in each case for the old method and for the new method, you still find a great advantage. Let somebody take, for example, an induction coil and arrange the battery-circuit, contact-breaker, etc., in the old way as well as he can, and let Mr. Duddell use the same induction-coil, battery, condenser, etc., and deal with it as well as he can, then the spark produced in the latter case will be from  $2\frac{1}{2}$  to 3 times as long as in the former.

There is one other point which has come out in connection with these experiments of a rather different kind. Some ten or more years ago a paper was read by Dr. Sumpner and myself before the Royal Society, pointing out what was then new, that in the case of an alternating-current arc, if we used solid carbons, the true power given to the arc, that is the power measured by some accurate method, was considerably less in some cases than the current measured by a good current ammeter multiplied by the pressure measured by an alternate-current voltmeter. Subsequently to that, in making experiments I was pretty convinced that under certain circumstances a direct-current arc behaved in the same way. I was pretty certain, in the case of a direct-current arc, especially when solid carbons were used and the arc was hissing, that the power-factor was no longer unity, but not sufficiently sure of the fact to publish it, especially in view of the way in which that other paper which I have just referred to was received at the Royal Society, and the scepticism which was raised when Dr. Sumpner and I pointed out how far from unity we found the power-factor was with certain alternate-current arcs. But now I am sure, from results of experiments which have been recently made in my laboratory, that with an arc supplied with accumulators, a so-called steady direct-current arc, if the carbons be solid and there is hissing, the power-factor may be several per cent. different from unity—that is, the true power as measured by a true instrument, for example a good wattmeter, may be several per cent. less than the product of the voltmeter reading into the ammeter reading.

When I read this paper of Mr. Duddell's, I thought he had proved that a solid carbon direct-current arc was the most sympathetic soul I had ever met, but you have convinced us that that is not quite the case for you have shown Mr. Duddell this evening that the sympathy of his arc is even exceeded by the sympathy of his audience.

[fol. 2944]

DEFENDANT'S EXHIBIT Z

United States of America,  
Navy Department,  
Washington, July 7, 1923.

I hereby certify that the annexed Blueprint copy of "Belini-Tosi Direction Finder Tests", prepared by Mr. George H. Clark, while on duty at the Radio Test Shop, Navy Yard, Washington, D. C., in the year 1915, is a correct copy of the original now on file in the Radio Test Shop, Navy Yard, Washington, D. C.

F. H. Brumby, *Captain, U. S. Navy, Acting Commandant.*

Office of the Secretary.

I hereby certify that F. H. Brumby, Captain, U. S. Navy, who signed the foregoing certificate, was at the time of signing Acting Commandant, Navy Yard, Washington, D. C., and that full faith and credit should be given his certification as such.

In testimony whereof, I have hereunto set my hand and caused the Seal of the Navy Department to be affixed this fifteenth day of July, one thousand nine hundred and twenty-three.

(Seal.) T. Roosevelt, *Secretary of the Navy.*

*Bellini-Tosi Direction Finder Tests*

Radio Test Shop, U. S. Navy Yard, Washington, D. C.

Radio Laboratory,  
Navy Yard, Washington, D. C.,  
10-5-15.

## Test of Bellini-Tosi Direction Finder

## Enclosures:

- Photos: RW69P92 to RW69P100 inclusive (9  
photos)  
Prints: RW50A106A t  
RW66A101A RW69A92B  
RW69A56A to RW69A100A inclusive. (45  
prints)  
RW69A102A and 103A

[fol. 2945] 1. *Description of Apparatus.*—The apparatus consists essentially of the following parts:

- a. Two special antennas.
- b. One direction-finder system.
- c. One receiver with detector and accessories.
- d. One angle-bisector.
- e. One tester.

(a) The antenna system consists of two triangular, insulated, ungrounded antennas of equal size, the plane of one being exactly at right angles to the plane of the other. RW69A96A shows a typical aerial on land, and RW69A94A shows the method of installation on shipboard. Since by far the greatest use of the device is on shipboard, the names assigned to the aerials correspond to the location of the aerial with reference to the ship. One aerial is called the "Port forward-starboard aft" aerial, the other the "Port aft-starboard forward" aerial. Similarly, the horizontal leads from the lower ends of the sloping antenna wires to the receiving apparatus are known by the quarter of the ship in which they lie, as "Port forward", "starboard aft", etc. As shown in the drawing, the planes of the aerials lie at an angle of forty-five degrees with the fore and aft plane of the ship; this is done in order to obtain as great a length of base line as possible. Other things being equal, the dis-

tance-efficiency of the direction-finder increases with increase in base line.

When installed on shipboard, the triangular aërials are usually suspended by their top corners thru insulators from a triatic or other fore and aft stay, or from a sprit, gaff, or bracket on one of the masts. Connecting wires are led to the instruments from the centres of the horizontal base lines of the triangular aërials, which are split by an insulator at their point of intersection. The range of the installation suffers to some extent if these connecting wires are very long, so that it is desirable to keep the distance between the instruments and the centre of the aerial system as short as practicable.

(b) The direction-finder system consists of two coils of wire of equal size, crossing each other at right angles in vertical planes. In the middle of each coil of wire is inserted a variable condenser of the sliding plate type; this location being for reasons of symmetry. Inside the crossed coils a third coil, called the "exploring coil" is mounted on a vertical spindle, so that its angular position with reference to the fixed coils can be varied. On this spindle is mounted the indicating handle from which the direction is finally read. RW69P92 shows the exterior of the Direction-Finder, and RW69P95 the interior. The connections of the primary coil system are shown in print RW69A92A; the dimensions and value of the primary coil system in RW69A83A; the mechanical details of the sliding plate condenser in RW69A82A; and the calibration of this latter in RW69A81A.

Each aërial passes thru a double pole switch, which, when opened, completely disconnects the aerial from its associated coil system. Safety spark gaps serve to take care of any high potential developed in the aerial due to the local transmitter or other causes.

[fol. 2946] The inductance of one side of one of the primary coils is 0.0046 m. h., and the total inductance of the two halves of one coil is 0.018 m. h.

The series primary condenser has a maximum value of 0.0014 mfd. The fixed plates are provided with an adjusting screw, so that the absolute value of capacity at any given setting may be varied within certain limits. The series condensers of both aërials are varied simultaneously, hence if there should be a slight dissimilarity in the constants of

the two aerials both would not be exactly in resonance if both condensers had exactly the same value. Hence by the adjusting screw any difference in antenna constants can be offset once for all by a variation in the value of the series condenser associated with the antenna, the other series condenser remaining unchanged.

The pick-up coil which rotates inside the primary cage is shown as coil  $L_2$  in RW69A77A. Its inductance is 0.155 m. h. at 1,000 meters.

(c) The receiver system is shown in photos RW69P93, 94, 96, 97, and 98. The wiring is shown in print RW69A92A.

The intermediate circuit which acts to transfer energy from the primary squirrel-cage coil system to the detector system consists of two coils and a variable condenser, all three being in parallel with each other. The variable condenser is of the Marconi ebonite-plate type, and has a maximum capacity of 0.011 mfd. This is very much greater than is required to reach the wave lengths intended when used with the associated coil system. An air dielectric variable condenser would be far preferable. The calibration of this Marconi condenser is shown in RW69A78A. The constants of the intermediate circuit inductances and of the detector circuit inductance and the coupling between these circuits is shown in RW69A77A. This coupling is variable by a handle projecting from the receiver box, and marked "Intensifier bar (le)". The choice of term is not ideal.

The detector circuit consists of a cylindrical inductance of value 0.60 m. h. at 1,000 meters, and a sliding tubular condenser, this latter being known as a "billi" condenser. The term is given on account of the mythological value of capacity supposed to be available with this condenser, i. e., one billionth of a farad. As a matter of measurement, the condenser varies from 0.000016 mfd. to 0.00024 mfd. The construction of the condenser is shown in RW69A80A, and the calibration in RW69A79A. This condenser is also known as the "jigger" condenser.

Two detectors were supplied with the set, (1), carbon-drum, and (2), Fleming valve.

The general diagram and also RW59A106A show the diagram of connections for the valve. A series resistance  $R_h$  varies the filament current and hence the brilliancy of the filament. A potentiometer  $RH$  varies the potential

on the enveloping plate. These resistances are in series with each other, hence a variation in the series resistance (to vary the filament brilliancy) requires a readjustment of the potentiometer. A ~~six~~-volt storage battery is used for current supply. This battery with its associated charging [fol. 2947] ing and connecting plug, and also voltmeter, is shown in RW69P98.

When using the crystal detector, the potentiometer alone is in use. The series resistance is in circuit, but is no longer a factor in adjustment.

A simple two way switch serves to connect valve or crystal.

(d) In obtaining the direction of a sending station, as explained in the next paragraph, greater accuracy is obtained by noting the position on each side of the maximum at which signals die off to a certain equal value. The direction-indication is then the mean of these two angles on either side of the maximum. For rapid determination of this mean angle an angle-bisector is supplied with the apparatus. See photo RW69P100. If the two outer arms be set at angles corresponding to the reading of the direction finder each side of the maximum position, the middle arm automatically indicates the mean of these two angles.

. . . . .

2. *Operation of Direction Finder.*—Each aerial loop forms a directional aerial, which receives best when its plane is in the direction of the sending station. If the plane of the aerial is at right angles to the direction of the sending station, equal and opposite currents are set up in each side of the loop, and the net result is zero. When the plane is in the direction of the sending station, currents of different phase are set up in the two sides of the loop, the phase difference depending on the relation between the wave length and the length of the base line of the aerial. Hence a resultant current flows thru the system. When the plane of the aerial is intermediate between the positions described above, the induced current varies as the cosine of the angle between the plane of the aerial loop and the direction of the sending station.

. . . . .

3. *Experiments With the Direction Finder.*—Tests made between May and September, 1914.

f. *Sending station.*

• • • • •

g. *Receiving aerials.*—A number of aerials were rigged up for use with the Direction Finder, utilizing for this purpose the main and topmasts of the wooden mast then existent at the Navy Yard.

• • • • •

h. *Effect of removing direction finder to station 90° distant.*

• • • • •

i. *Effect of main flat-top aerial on direction indication.*

• • • • •

j. Plot of current in each aerial and resultant current in direction-finder.

• • • • •

[fol. 2948] k. *Effect of coupling between intermediate and detector circuits on direction-indication.*

• • • • •

l. *Effect on direction-indication of detuning both aerial circuits equally (by series condenser).*

• • • • •

m. *Effect on direction-indication of detuning one aerial circuit, the other remaining at resonance.*

• • • • •

n. *Effect on direction indication of error in bearing of one side of one aerial.*

• • • • •

o. *Determination of direction of distant lightning disturbances the Direction Finder.*

• • • • •

p. *Comparison of aerials with (1) base line 180°, and (2) 200°.*

• • • • •

q. *Tests of various primary circuits.*

• • • • •

r. Test of relative sensitiveness of detectors. Method of test: Signals sent at constant power from portable set at War College. Shunts taken on receiving telephone. One side of another telephone in series, unshunted, as permanent choke. Wireless Specialty adjustable telephones, D. C. resistance 1000 ohms.

Carborundum detector as supplied with Direction Finder 80 audibility.

Fleming valve as supplied with Direction Finder 160 audibility.

Galena crystal and copper wire contact (From Wireless Specialty receiver) 400 audibility.

After the first few tests on the Direction Finder, the galena detector was used for all tests.

s. Tests of direction:

. . . . .

t. Sensitiveness of direction finder apparatus as a whole.

. . . . .

u. Reactance curves of aerial systems.

. . . . .

v. Recommendations:

1. Replace secondary condenser (Marconi type, with ebonite dielectric) by standard air condenser. Present condenser is much too large for the wave lengths normally used with the apparatus, is liable to get out of order, and has serious internal losses.

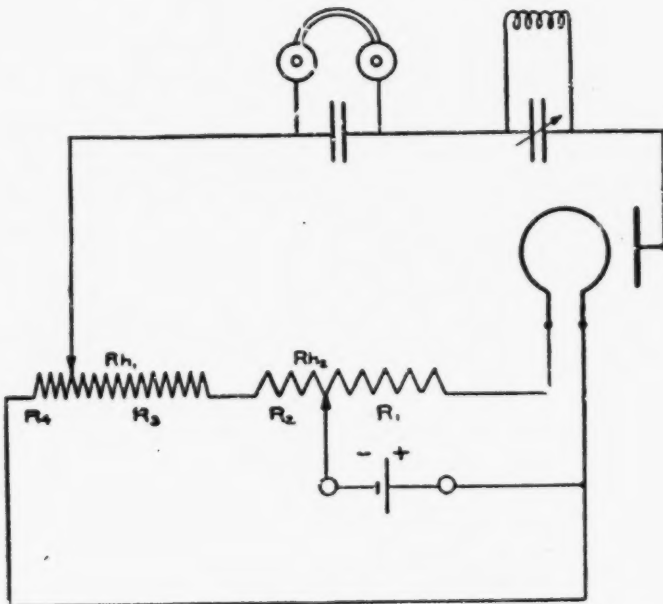
2. Replace carborundum detector and Fleming valve by more sensitive crystal detector (as galena or silicon-arsenic) and DeForest audion amplifier. Possibly it would be sufficient to supply binding posts for this, and use the detectors available at the station of use.

[fol. 2940] 3. Tests should be begun to devise a method of direction finding which, as this one, is independent of the movement of the ship, (i. e. does not require orientation of the ship to determine direction), but which has a much greater range. The limited range of the Bellini-Tosi ap-

paratus, even on land where an antenna of considerable size can be erected, is a severe disadvantage to the system.

Approved.

A. L. Winary, Commandér, U. S. Navy, Engineer Officer.



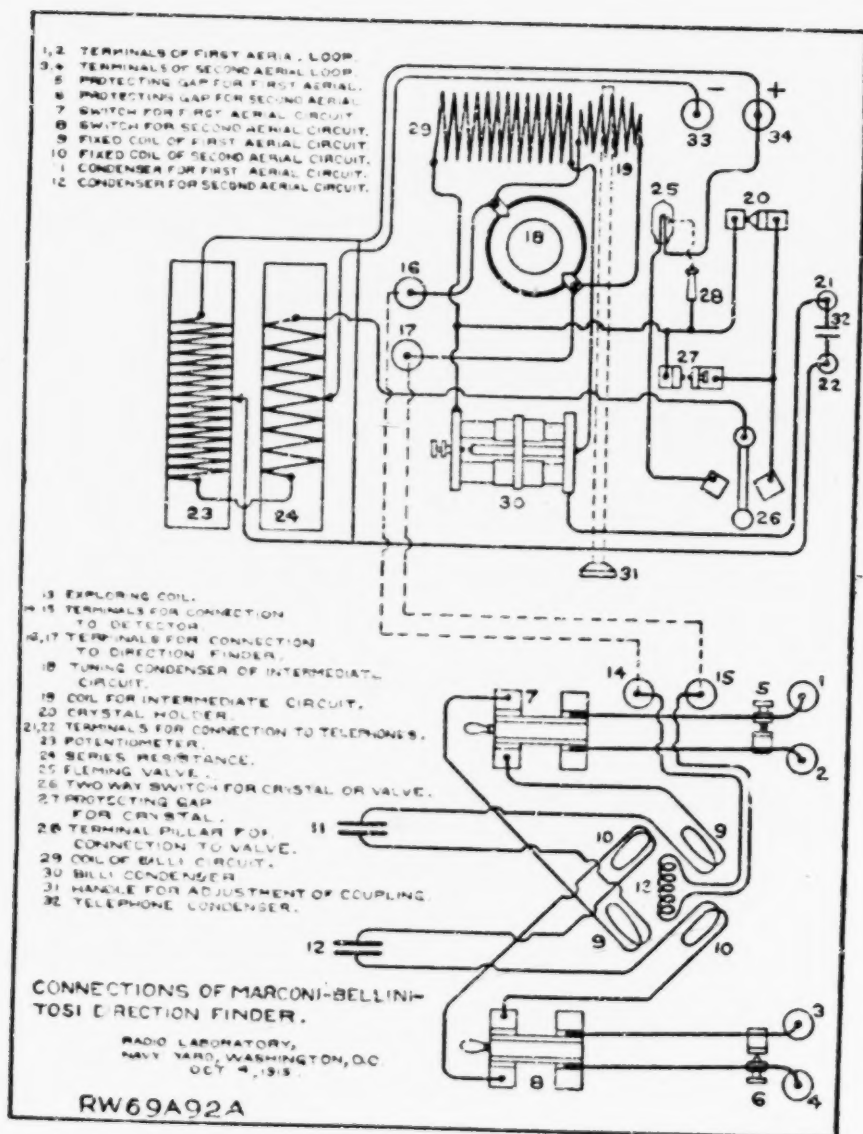
MARCONI DIRECTION FINDER  
CONNECTIONS FOR  
FLEMING VALVE.

NAVY YARD,  
WASHINGTON.  
10-1-15.

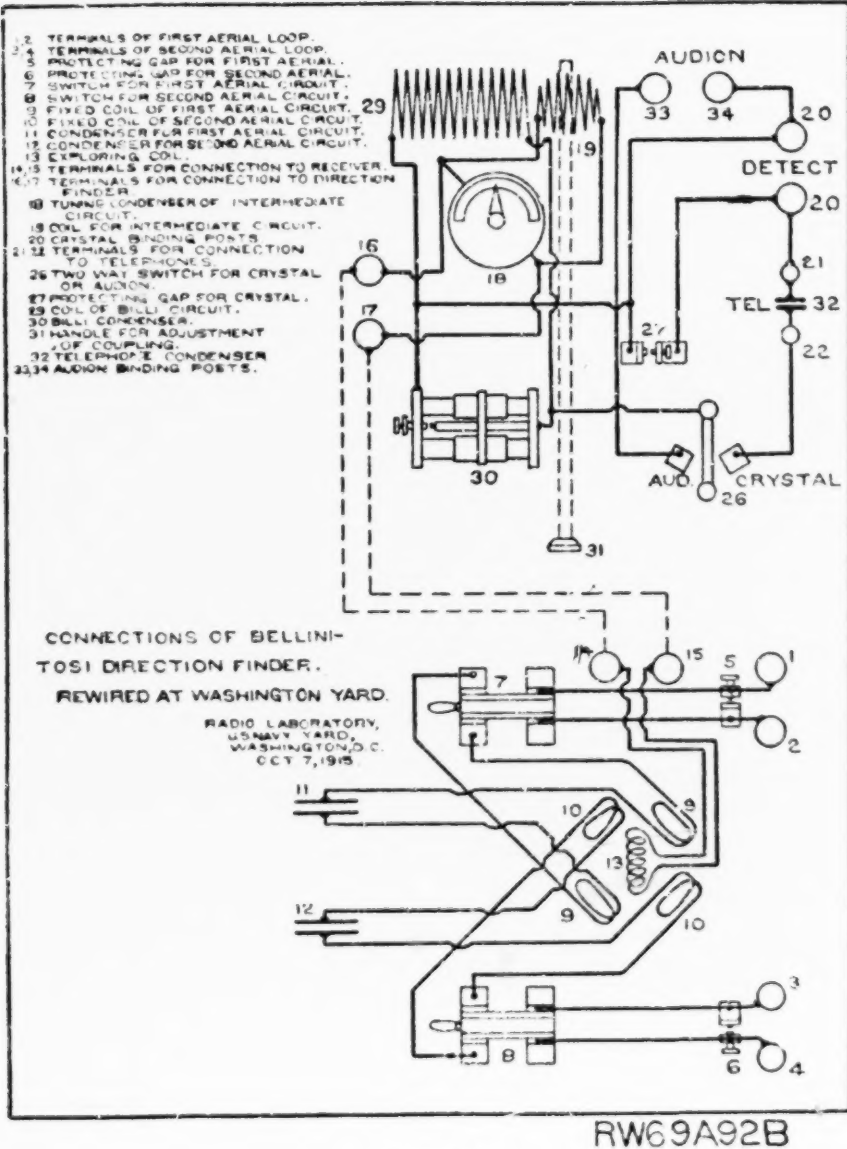
From RW69A92A  
of 12-27-14.

RW50A106A

[Vol. 29, 50]



[Vol. 2951]



## DEFENDANT'S EXHIBIT A-1

*Manual of Wireless Telegraphy (Radio)*

For the use of Naval Electricians by Commander S. S. Robison, U. S. Navy, 3d Revised Edition, Annapolis, Md., the United States Naval Institute, 1915

U. S. Naval Wireless Telegraph Station, Sitka, Alaska.

199. The variable inductance of fig. 83 is hinged so that the coupling can be varied by a combined movement of

separation and rotation with reference to the fixed inductance (fig. 100).

[fol. 2952] In fig. 86 the coupling is varied by sliding the closed circuit inductance on a graduated bar parallel to its axis (fig. 101a).

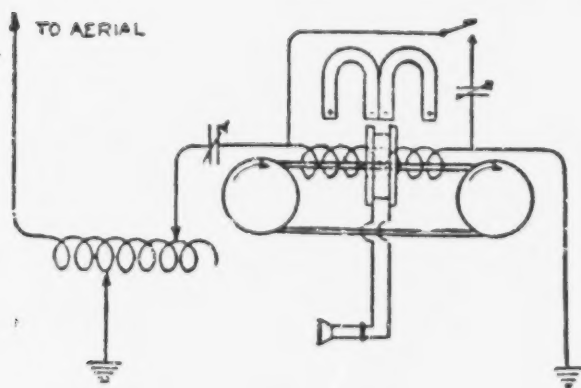
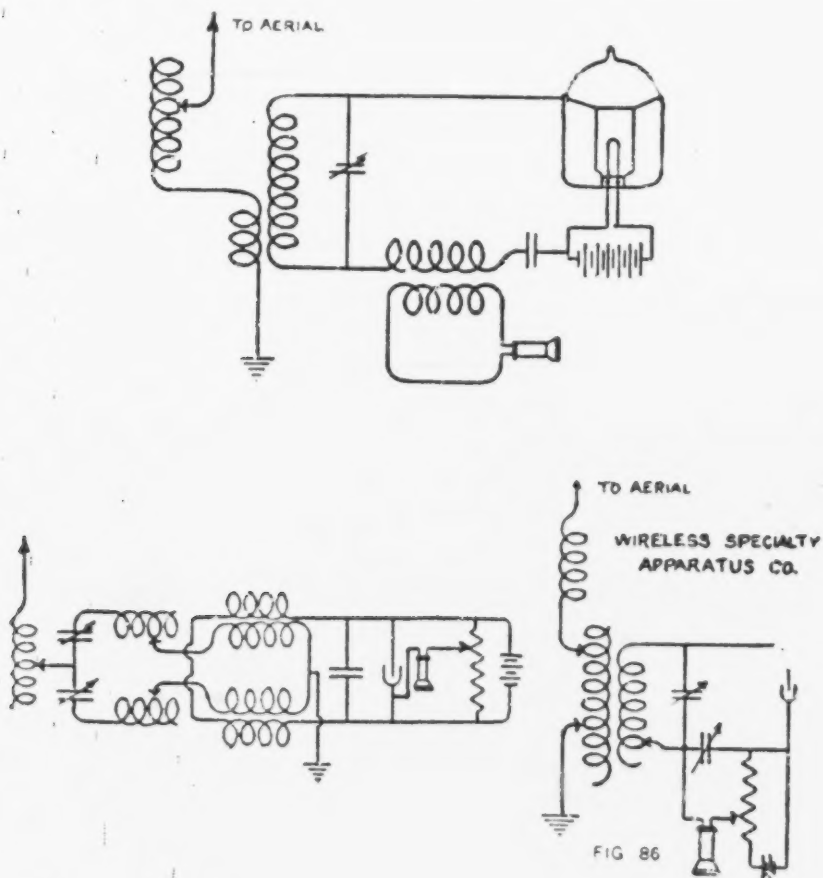


FIG. 87 - Magnetic Detector - Marconi.

Figs. 84 and 88 represent the valve and audion receiving circuits. In fig. 84, the valve detector is shown as shunted [fol. 2953] around a tuned, closed circuit. The audion shown in fig. 88 has tuned connections like the valve detector, but has a focal battery in the telephone circuit.

Fig. 92 represents circuits of a receiving set complying with present specifications. In all such sets closed circuits are calibrated and curves drawn on a scale furnished show-

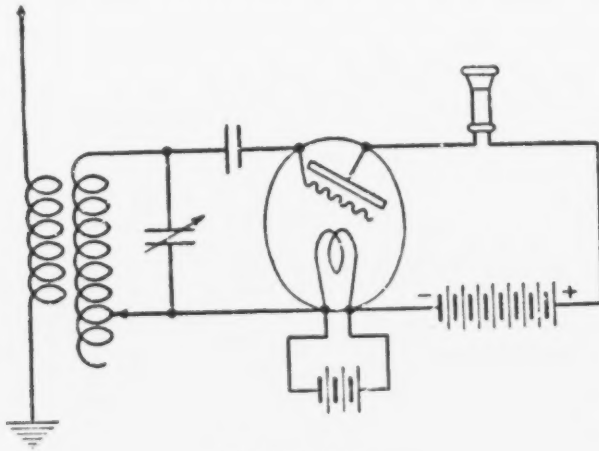


FIG. 88.—Audion.

ing wave lengths for all settings from 200 to 4000 meters, and additional calibrated loading coils for very long waves are supplied.

With very loose coupling the wave length of received signals can thus be read directly.

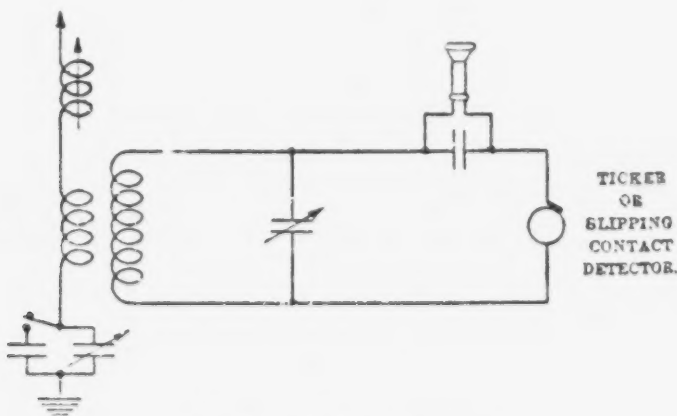


FIG. 89.—Federal Co. (Poulsen).

200. Fig. 89 represents receiving circuits for continuous oscillations; it shows the receiving telephone connected across the terminals of a fixed condenser in series with the detector.

In using undamped oscillations for wireless telegraphic purposes it must be remembered that the frequency of the oscillations themselves is too high to be heard in the telephone connected with the ordinary receiving circuit, and when the circuit at the sending station is closed all that would be heard is a slight click, so that there is no way of [Vol. 2954] telling a

being wound in a spiral groove on an ebonite cylinder. A sliding contact, on a rod parallel to the cylinder, works in the groove and is pressed against the wire by a spring. By revolving the cylinder an infinite number of adjustments can be obtained.

Earlier Fessenden sets (figs. 79 and 82), have double roller inductances, by turning which, the wire can be reeled from one roller to another as desired. On one roller the turns are insulated from each other and on the other they are short circuited so that any desired length can be retained in the circuit.

None of the above types of variable inductances can be readily mounted so as to vary the mutual induction between them by any definite amount. They are suitable for loading but not suitable for loose coupling.

For this reason the preferred types of receiving circuits are made up of fixed inductances (or those varied by plug or dial steps), mounted so that they can either be pulled apart or one coil revolved so as to change its plane and hence the mutual induction with reference to the other or others. The variometer type, mounted like variable condensers, are now being manufactured. Their self induction can be varied quickly and conveniently and close adjustment of period (tuning) made with them or with the variable condensers, but the entire coil is always in circuit.

Each section of an inductance not in circuit should be opened at both ends, i. e., entirely disconnected, and if its natural period is large it should be mounted so that the inductive effect of active parts on it is a minimum. This applies especially to loading coils for long wave lengths. (Fig. 92.)

All inductances are wound on hard rubber, porcelain or glass and so as to have a minimum high frequency resistance. The decrement of the entire circuit must not exceed .3.

From the formula for damping  $d = \frac{R}{2nL}$  it can readily be seen that a very pronounced natural period—a stiff circuit—can not be obtained unless the self-induction is large compared with the total resistance (including the radiation resistance.)

205. *Detectors.*—There is but one type of detector now in general use, viz., the *Crystal* or rectifying detector. The *electrolytic* is used only as a standard for comparison. Coharers and microphones are practically obsolete, and comparatively few of the magnetic and audion, or valve detectors, have been installed, but the use of audions and ultra-audions is increasing. Unlike coherer detectors, all types of crystal, magnetic, electrolytic and audion detectors are self-restoring. Generally speaking all should be put on open circuit while sending, to preserve them from injury due to induced potentials and currents.

The ordinary detector serves as well for receiving the continuous modified oscillations of *wireless telephony* as for the groups of oscillations in ordinary *wireless telegraphy*.

[fol. 2955] 206. *The electrolytic detector.*—It consists of a fine platinum wire just touching an electrolyte made either of a 20% solution of nitric or sulphuric acid or an alkali. Of these the nitric acid solution is preferred. The other electrode is also of platinum. The containing cup (fig. 79) is made quite small so that the cohesive power of the electrolyte will prevent splashing in a sea way. The electrolytic detector must have the fine wire terminal connected to the positive pole of the local battery (fig. 79), otherwise the device is not operative.

Dr. Austin states that the higher the frequency, the finer the wire should be, and that the depth of immersion does not matter if the detector is not directly in series in the closed circuit.

When a current flows through the electrolyte, the latter is decomposed (the action being called electrolysis) liberating oxygen at the anode and hydrogen at the cathode. The accumulation of these non-conducting gases on the electrodes

interferes with the passage of the current, which soon ceases to flow and the cell is then said to be *polarized*.

The fine wire anode is then insulated by the oxygen, which forms the dielectric of a small condenser, of which one conducting surface is the electrolyte and the other the wire point.

The critical potential of the detector is just below that necessary to break down this insulating layer of oxygen and is determined by increasing the potential at the detector terminals by means of the potentiometer until a bubbling or hissing sound is heard in the receiving telephone; then resistance is cut in until this sound just ceases.

When electric oscillations are impressed on this condenser, the polarization layer breaks down and permits a pulse of direct current from the battery to pass through the cell and *telephone*. As soon as the oscillations cease the polarization is restored.

Except when they are very strong, the loudness of the sounds produced in the telephone is an exact measure of the energy of the oscillations passing through the cell.

This constancy of action of the electrolytic cell is utilized as a means of comparing the sensitiveness of detectors, the standard being the sensitiveness of an unjacketed platinum wire electrode .0002 in diameter in a solution of 20% nitric acid.<sup>1</sup>

Glass jacketed electrodes formed by sealing the wire in glass (the two having the same coefficient of heat expansion) have been used, but are less reliable and in general less sensitive and are no longer supplied. Some of these glass points were made hook shaped, the hook pointing upward to facilitate depolarizing but no increase in sensitiveness was noted on this account.

With the Shoemaker receiving sets was furnished what was called a primary cell detector. The electrolyte used was a 20% solution of sulphuric acid and the other electrode was a zinc rod amalgamated with *mercury*, which in the acid solution gave a difference of about .7 volt between zinc [fol. 2956] and platinum. No local battery was required (fig. 82). At times this detector compared favorably with

<sup>1</sup> Dr. Austin has invented a "detector tester" which affords a means of direct comparison between detectors operating under the same conditions.

the one just described, but was in general more irregular and less sensitive in its action.

In all electrolytic detectors very strong signals or static discharges produce actual sparking or an explosive action in the electrolyte, which destroys the platinum point and an operator must be constantly on the lookout to protect his point from burning out. The best results in electrolytic detectors have been obtained with a distance between electrodes of approximately  $\frac{1}{4}$  inch.

207. *Rectifying detectors.*—There are certain substances which when brought together in not too close contact, have the property of producing a direct current when an alternating current or electrical oscillations are sent through them. The cause of this action is not yet known. Among these substances are carbon in contact with steel, tellurium with aluminum or galena, silicon with any of the ordinary metals, and certain crystals.

The first of the crystal detectors to be supplied was General Dunwoody's carborundum crystal detector.

Since rectifying detectors permit the passage of current in but one direction, they produce pulses of direct current. These pulses, if strong enough, can be heard in a telephone so that local batteries are not required, although a slight increase of sensitiveness is noted in some detectors with an E.M.F. across the terminals of the detector of about 0.2 volt.

Rectifying detectors are connected in receiving circuits in the same manner as the electrolytic.

Their sensitiveness for general use is practically equal to the electrolytic and their simplicity makes them the more suitable. They are in general less sensitive to injury from static discharges, strong signals, or induced currents from sending, than the electrolytic, but, like coherers, different crystals of the same material vary widely in sensitiveness and sensitive spots in any crystal have to be found by trial and when found are not constant. They are thus not as capable of quick readjustment as the electrolytic, but their other advantages are such as to be conclusive as regards their use.

The carborundum detector when first introduced, was simply held between two points or wrapped with copper wire for one connection, with a needle, knife edge, or more blunt piece of metal for the other. It was later found that embedding a large part of the crystal in a conductor such

as solder or a mercury paste, and thus limiting the rectification to one contact only, produced much better results and carborundum crystals have been found equal in sensitiveness to other crystals now generally utilized.

Pickard's silicon detector followed the carborundum and is still in use but it has been largely superseded by the Perikon & Pyron, supplied with the receiving set illustrated in fig. 86. The Perikon detector consists of two crystals, chalcopyrites and zincite. A number of zincite crystals are held in a conducting disc, a crystal of chalcopyrites is mounted [fol. 2957] so that it can be brought into contact with any part of any of the zincite crystals at will, and the pressure between the two *regulated*. In the adjustment for maximum intensity of signals, the exact degree of pressure and the most favorable points of contact are of importance. These can only be ascertained by trial and test with the testing buzzer.

The sensitiveness of the Perikon may be approximately doubled by connecting a battery across its terminals so as to give approximately 0.2 volt. The positive pole must be connected to the single crystal.

The Pyron consists of a crystal of iron pyrites in contact with a metal point like the silicon. This is very satisfactory for strong signals and constant in its action. The iron pyrites is more sensitive when the pressure of the metal point is adjustable. The *area* of contact is also a determining factor of sensitiveness; comparatively fine points will discover sensitive places on irregular crystals, which blunt points will not.

The Perikon is more sensitive and must be protected against strong signals. The *zincite* is the crystal injured by strong signals. It should not be subjected to heavy pressures or grinding from the chalcopyrite. When deadened the zincite crystals can be made operative by scrubbing them with a bristle brush wet with carbon bisulphide, then with soap and water and then rinsing with fresh water and drying. In damp weather or in tropical climates this detector is improved by spreading a drop of paraffin oil over the surface of the crystals. This comment applies to the silicon also.

Galena, cerusite (a form of galena), and iron pyrites are all giving satisfactory use by mounting so as to have contact all over one surface and a very fine, flexible wire point, just touching *the other* surface.

208. *Vacuum tube detectors*.—The two forms which have been used are known as the valve and the audion, illustrated in figs. 84 and 88. The valve was discovered by Fleming, and is sometimes called the Fleming valve. It is a rectifier, permitting the passage of current in one direction only. It consists of a special incandescent lamp (see fig. 84), operated by a 12-volt storage battery and having a small sheet or cylinder of metal held in the bulb near the filament. Lamp filaments when glowing emit negative electricity, which carries away part of the filament and causes the darkening of the bulb seen on old carbon lamps. The vacuum thus becomes a conductor in one direction only. It is not found to be a very sensitive one.

The audion (fig. 88) has a metal grid interposed between the metal plate and the lamp filament. In the valve, the metal plate is connected to the receiving circuit, but in the audion, the grid is connected to the receiving circuit, while the plate is connected to the telephone. In the valve, the variations of current in the receiving circuit produce differences of potential between the filament and the plate. In the audion, these differences of potential are between the filament and the grid: or, as it is perhaps better to say, the grid is charged by the received oscillating currents. In [vol. 2958] addition to this difference, the audion has a local battery with its positive pole connected to the metal plate, and its negative pole to the lamp filament. This battery, as well as the battery supplying the lamp, has a variable voltage. The battery voltage and lamp voltage must both be adjusted to secure the greatest sensitiveness of this detector; but this adjustment is permanent for any given conditions. The charge on the grid, produced by the incoming signals, interferes with the flow of negative electricity between the filament and the plate. This flow of negative electricity, when the heat from the filament and the local

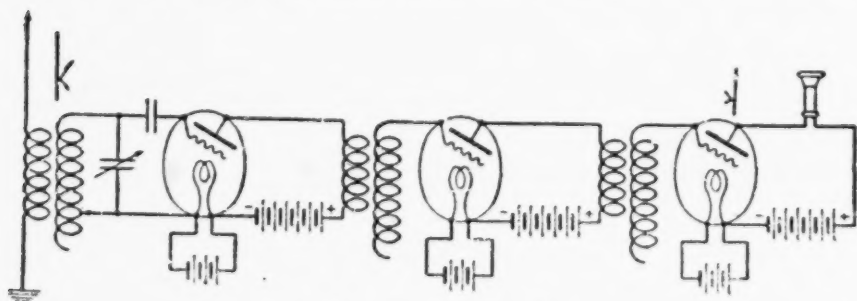


FIG. 88A.—Amplifying Audion.

battery voltage are properly adjusted, produces a current through the audion of the order of a milliampere. This current flows through the receiving telephone and variations in it, produced by the varying charge on the grid, are what make the signals heard in the telephone.

The audion has the further advantage over the valve, in that the telephone can be replaced by the primary of a transformer, the secondary of which is connected to another audion, with the result of amplifying the signals produced. (See fig. 88a.) Audion bulbs have tantalum lamp filaments, and plate and grid are usually double, one on each side of the filament. The plate and grid are of nickel. The audion can also be used as a heterodyne (art. 201). When connected for receiving continuous oscillations it is called "the ultra-audion."

We see, therefore, that the audion is suitable for use with arc, as well as spark sets, and also as an amplifier: thus combining within itself the qualities of all other detectors.

209. *Magnetic detectors.*—The operation of magnetic detectors depends on the fact that when iron is being magnetized its magnetization is somewhat delayed in time behind the impressed magnetizing force, and when in this condition the iron is very sensitive to any change in the magnetizing force, a very small increase of which will produce a momentarily large increase in the strength of the magnetic field.

Many patents have been issued for various forms of magnetic detectors, the best known and the most largely used of which is Marconi's, patented in England in 1902. It is not [fol. 2959] injured by strong sending, but is not as efficient as the crystal detector, the electrolytic nor the audion.

In its present form it consists of a flexible band of silk-covered iron wires, moved by clockwork around two pulleys which support it. A glass tube, through which the band passes, has a primary winding of insulated wire in series with the aerial and a secondary winding forming a closed circuit through a telephone. Close to the secondary windings are placed similar poles of two horse-shoe magnets, which magnetize the iron band slowly moving under them. Electric oscillations in the primary winding, produced by passing electric waves, produce momentary changes in the magnetization of the iron band under the magnets, and

these changes induce oscillating currents in the secondary winding which produce sounds in the telephone.

An elementary diagram of this magnetic detector is shown in fig. 87. It requires no local battery, and, not being subject to burnouts except from very large currents, it is a very convenient instrument, but is not as sensitive as those previously described, especially for short wave lengths. There are other methods of connecting this detector than that shown in fig. 87, but since comparatively few magnetic detectors are in use they are not shown here.

#### DEFENDANT'S EXHIBIT B 1

*Robinson's Manual of Radio Telegraphy and Telephony.*  
1918

205. *Detectors.*—There are two types of detectors now in general use, viz., the *Audion*, and the *Crystal* or rectifying detector. The *electrolytic* is used only as a standard for comparison. Cohers and microphones are practically obsolete, and comparatively few of the magnetic detectors have been installed, but the use of audions and ultra-audions is increasing. Unlike coherer detectors, all types of crystal, magnetic, electrolytic and audion detectors are self-restoring. Generally speaking all should be put on open circuit while sending, to preserve them from injury due to induced potentials and currents.

The ordinary detector serves as well for receiving the continuous modified oscillations of *wireless telephony* as for the groups of oscillations in ordinary *wireless telegraphy*.

206. *The Electrolytic Detector.*—It consists of a fine platinum wire just touching an electrolyte made either of a 20% solution of nitric or sulphuric acid or an alkali. Of these the nitric acid solution is preferred. The other electrode is also of platinum. The containing cup (fig. 79) is made quite small so that the cohesive power of the electrolyte will prevent splashing in a sea way. The electrolytic detector must have the fine wire terminal connected to the positive pole of the local battery (fig. 79), otherwise the device is not operative.

*Wireless Telegraphy and Telephony*

An Outline for Electrical Engineers and Others by

L. B. Turner, M.A., M.I.E.E., Fellow of King's College, Cambridge; recently of the Signals Experimental Establishment, Woolwich (Royal Engineers), and of the Engineer-in-Chief's Office, Post Office; Member of the Imperial Wireless Telegraphy committee 1919-20. Cambridge, at the University Press, 1921

example, the triode<sup>1</sup> produced by H. J. Round of the Marconi Company, shown at C in Plate XVII, would generally give wonderful results in expert hands; but it had to be carefully nursed, and its vacuum was actually controlled by the operator from time to time by warming more or less the pellet of asbestos sealed in a pocket in the tube, and visible in the photograph. In other tubes, a mercury amalgam was introduced for a similar purpose.

6. *Introduction of third electrode.*—We pass now to the effect on the space charge of introducing into it, or near it, a third electrode, maintained at a higher potential so as more or less to neutralise the charge. The tube then becomes a three-electrode tube, and is called a "triode." The third electrode is usually in the form of a perforated plate, or a wire grid, placed between cathode and anode, and is commonly called the "grid."<sup>2</sup> The introduction of the grid was the work of L. de Forest in 1907, and although the rationale of the triode does not appear to have been fully understood at the time, and its uses have only recently been developed, this addition to the Fleming Valve marks the conversion of the thermionic tube from a mild convenience into the potent and indispensable instrument it is to-day.

The reader will be helped to some physical picture of the action of the grid by studying the diagrams in Fig. 58. Here

<sup>1</sup>The fact that this is a triode and not a diode is irrelevant in this connection.

<sup>2</sup>"Control electrode" (grid) and "repeat electrode" (anode) are good descriptive terms, used by Eccles. Most commonly, the electrodes are referred to as filament (or cathode), grid, and anode (or plate).

C, G and A are sections of the cathode, grid and anode, which may be regarded for simplicity as portions of large plane surfaces perpendicular to the paper. The diagrams are intended to show the lines of electric force in the space between anode and cathode which would act upon the electrons if any were present, urging them to move in the direction against the arrow-head (since the electron is a *negative* charge). The presence of the electrons modifies the field in a manner not easy to portray, but by first considering the field in their absence we can obtain some insight into the action of the grid. To arrive at the electron currents, which are stated on the right of the diagrams, we have to picture a cloud of electrons congregated near the cathode, repelling freshly evaporated electrons.

[fol. 2961]

DEFENDANT'S EXHIBIT D-1

*Guide to the Study of the Ionic Valve*

Showing its Development and Application to Wireless Telegraphy and Telephony, by William D. Owen, Associate Member of the Institute of Electrical Engineers, Head of the Department of Wireless Telegraphy, Rutherford College, Newcastle, 1919

IV. *The "Audion" or Three-Electrode Valve.*—The two-electrode valve is now obsolete except in a modified form called the "Kenotron," to which reference is made later on. It was abandoned in favour of carborundum, which is more sensitive and requires less auxiliary apparatus. By the introduction of a third electrode into the valve between filament and plate, Dr. Lee de Forest, of New York, made use of an entirely new principle. The additional electrode must be such as to have capacity with respect to the filament and, in spite of its position, must allow electrons to pass to the plate. Incidentally it might be mentioned that the capacity effect between the *plate* and the third electrode is made use of in some circuits.

DEFENDANT'S EXHIBIT E-1

*Proceedings of Physical Society of London, 1914*

This shows the "Perikon" or zincite-chalcopyrite detector to be the most sensitive of those tested when used as a simple rectifier. The table also gives the maximum meas-

ured values of the sensitiveness for the various detectors tested when used with boosting voltage.

Table showing the relative sensitiveness of various detectors.

Detector	Maximum sensitiveness when used as simple rectifiers	Maximum measured sensitiveness with boosting voltage
Marcou magnetic, assumed as unity		
Molybdenite-copper point	2.15	2.15
Graphite-steel point	1.26	
Carborundum, one end set in solder	0.50	0.60
Carborundum, not set in solder	0.325	1.0
Galena-plumbago	8.35	12.6
Zincite-copper point	6.6	
Zincite-brass point	3.43	
Chalcopyrite-copper point	0	
Chalcopyrite-brass point	0	
"Perikon" (zincite-chalcopyrite)	10.5	12.1
Bornite-copper point	1.0	
Bornite-carbon point	0	
Zincite-bornite	7.4	7.4
Fleming carbon-filament valve (No. 12)		1.0
Fleming 12-volt metal-filament valve		1.0
Fleming 15 $\frac{1}{4}$ -volt metal-filament valve (No. 33)		12.0
Tellurium-aluminum		0.9
Electrolytic (German make)		1.0
Electrolytic nitric acid		4.0

<sup>1</sup>NOTE.—If the *general shape* of the sensitiveness curve for the galena detector may be assumed to remain the same for very light contact as for firmer contact (with which the above measurements were taken), the maximum *estimated* sensitiveness for this detector with very light contact is of the order of 60 to 70, as compared with the magnetic detector.

[fol. 2962] Since the exact values of the current, voltage, &c., obtained in these tests for the various detectors will necessarily differ with different crystals, tables giving the results of the measurements are not given, but sample curves are included to show the general form of these results, as the *general shapes* of the curves will probably remain the same for the same substances.

#### DEFENDANT'S EXHIBIT F-1

Department of Commerce and Labor. Bulletin of the Bureau of Standards, Vol. 6, No. 4, S. W. Stratton, Director. Issued November, 1910. The Comparative Sensitiveness of Some Common Detectors of Electric Oscillations. Louis W. Austin, 527. Washington, Government Printing Office, 1910.

*The Comparative Sensitiveness of Some Common Detectors of Electric Oscillations*

By Louis W. Austin

Although probably many comparisons of the sensitiveness of detectors have been made in the laboratories of the wireless companies, very little quantitative information on this subject has been made public. For this reason the experiments here described have been carried out. On account of the difficulties and the amount of time involved in the testing of detectors in wireless stations, methods have been developed during the last three years whereby these tests can be made in the laboratory more expeditiously and accurately than is possible in the regular stations. The difficulties usually encountered in laboratory tests of this kind are due mainly to the direct effect of the source of the oscillations on the receiving circuits and detector; but by using properly designed exciting circuits in connection with a buzzer as a source of oscillations these difficulties have been removed. As it is also possible in this way to produce oscillations of any required degree of damping as well as of any required wave length, all of the problems of wireless telegraphy can be successfully investigated in the laboratory except those which have to do with the properties of different types of antennae and the passage of the waves from station to station. In the following paper some experimental comparisons of the sensitiveness of wireless detectors are described.

Symbols

- $D$  = Galvanometer deflection / In general proportional to energy  
 $A$  = Telephone audibility      \      tional to energy  
 $I$  = Oscillatory current.      "      in detector.  
 $i$  = Direct current.  
 $R$  = Direct current resistance.  
 $R'$  = High frequency resistance.  
 $L_1 L_2$ , etc. = Inductances.  
 $C_1 C_2$ , etc. = Tuning condensers.  
 $K$  = Large fixed condenser 0.04-0.1 mf.  
 [fol. 2963]  
 $M_{34}$  = Mutual inductance between coils 3 and 4.  
 $d_{12}$  = Distance between coils 1 and 2.  
 $\lambda_1$  = Logarithmic decrement in circuit 1.  
 $\lambda$  = Wave length.

## METHOD OF EXPERIMENT

The exciting circuit<sup>1</sup> in all the experiments is shown in Fig. 1. Here  $B$  is a buzzer run by two storage cells with considerable resistance in series. The oscillatory circuit consists of a variable air condenser  $C_1$  having a maximum capacity of 0.005 microfarads, and for moderate wave lengths an inductance  $L_1$  of 0.062 millihenries. These are connected directly across the contact of the buzzer.

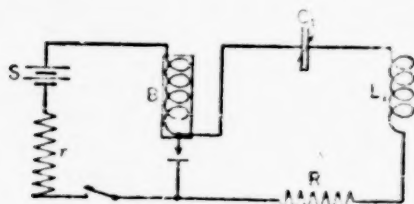


FIG. 1

The action of the circuit is as follows: When the buzzer contact is broken, the condenser  $C_1$  is charged and this charge is retained until

the contact is again closed, when the condenser discharges through the contact, producing oscillations in the circuit  $L_1C_1$ . As these oscillations take place in a closed metallic circuit, they are very feebly damped unless extra resistance is introduced at  $R$ .

All buzzers are not equally suited to producing oscillations by this method. In some, considerable adjustment of the contact is required before sharp tuning is obtained. The buzzer used in these experiments was of the 1905 United States Signal Corps type, and gave very satisfactory results with wave lengths varying between 350 and 2000 meters. With some care in adjustment the wave length could be pushed up beyond 3000. For telephonic reception of signals

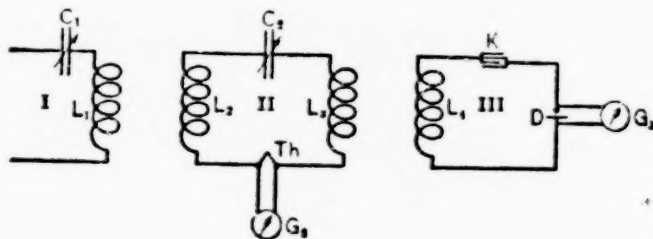


FIG. 2

<sup>1</sup> Other forms of buzzer circuit such as are used in several well-known types of wave meters were also tried, but with the buzzer used they gave less powerful oscillations than the one here shown.

it was usually found necessary to cut down the intensity of oscillations from the buzzer, and this was done by placing an incandescent lamp across the buzzer contact.

The chalcopyrite-zincite rectifier known as the perikon detector<sup>2</sup> was used as a standard for the comparison of the various detectors. As its sensitiveness varies somewhat from time to time, it was standardized before each experiment in the following manner, the circuits being shown in [fol. 2964] Fig. 2. Here *I* is the buzzer circuit, *II* a circuit containing a thermoelement of known sensitiveness, and *III* the circuit consisting of the perikon *D*, its coupling inductance  $L_3$ , and a suitable stopping condenser *K* of about 0.04 microfarad. With a given loose coupling between  $L_3$  and  $L_4$  the relation was noted between the reading of the galvanometer attached to the thermoelement and that attached to the perikon,<sup>3</sup> the condition of wave length and damping being kept constant. This relation gives at once the relative sensitiveness of the perikon. It was found better to take account of the variations in sensitiveness observed rather than to readjust each time to the same sensitiveness.

Table I shows the admirable proportionality between the deflections of the perikon detector and the square of the oscillatory current as measured by the thermoelement.

TABLE I—Comparison of tellurium-constantan thermoelement and Perikon rectifier.  
(See Fig. 2)

Thermoelement, Circuit II D	Perikon, Circuit III D	Ratio
2.3	25	10.9
5.3	54	10.2
9.7	100	10.3
19.8	198	10.0
31.2	330	10.6
41.3	480	10.9
51.7	540	10.4

$$L_2=0.03 \quad \text{mlh } \lambda=900 \text{ m}$$

$$L_3=0.425 \quad \mathfrak{Z}_1=0.16$$

$$L_4=0.420 \quad \mathfrak{Z}_2=0.13$$

$$M_{34}=0.025$$

Circuit III untuned.

<sup>2</sup> The perikon was a new one which had been little used and was of normal sensitiveness.

<sup>3</sup> The resistance in the perikon galvanometer circuit must be equal to that to be used in the experiment.

Two general methods have been used for measuring the sensitiveness for telephonic reception of radiotelegraphic receivers: First, the shunted telephone method in which

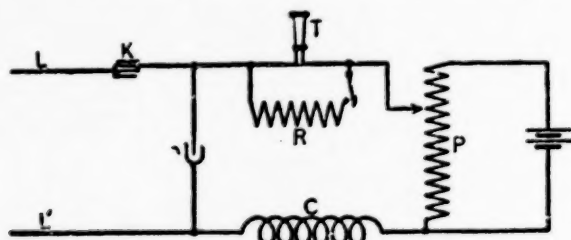


FIG. 3.

the relative loudness of response to the same signal in two different receivers can be compared, and, second, the variable coupling method by means of which the least audible signals for the different receivers can be compared.

[fol. 2965] A form of circuit for the shunted telephone method in the case of the electrolytic detector is shown in Fig. 3. Here  $L$  and  $L'$  are wires leading to the oscillatory circuit,  $K$  a stopping condenser of 0.04 microfarads capacity,  $T$  the telephones,  $R$  a variable resistance in shunt across the telephones, and  $C$  a choke coil to prevent the oscillations from running around through  $R$  instead of passing through the detector when the shunt  $R$  is closed. Two 60-ohm telephones form a suitable choke. Whatever choke coil is used it is necessary to test it by placing it across  $L$   $L'$ . If the choke is perfect, no oscillations will pass through it, and when it is placed across  $L$   $L'$  no change in the loudness of the signals will be observed.

The measurement of the intensity of signal is made as follows: After the receiving circuit and detector are adjusted to give maximum loudness in the telephone the shunt resistance  $R$  is closed and the resistance regulated until the signal just becomes audible. The value of the current pulses  $c$  in the telephone, which are proportional to the energy of the incoming waves in the detector, is expressed by the following well known formula, where  $r$  is the value of the shunt, and  $t$  is the resistance of the telephones, and  $c'$  the least current audible in the telephones:

$$c = \frac{r+t}{r} c'$$

$$\text{The audibility, } A = \frac{c}{c'} = \frac{r+t}{r}$$

The signal is often expressed in terms of  $A$  as being so many times audibility. With care a series of measurements of intensity may be made to agree among themselves to within about 10 per cent.

In the variable coupling method for comparing the least audible signals in two detectors, the deflections of the galvanometer connected to the perikon are observed for a number of different degrees of coupling between the inductances  $L_1$  and  $L_2$ . (See Fig. 2.) From these a curve is plotted which gives the variation of the received energy as determined by the distance between the coils. The coupling, for which the signals just become audible in the telephones of the detectors being compared, is then observed and the relative energy taken from the curve.

Fig. 2 shows the general plan of the circuits used in the comparison of the detectors. *I* is the exciting circuit adjusted to send out wave trains having a wave length group frequency and damping similar to those occurring in wireless practice. *II* is a circuit whose constants were made to correspond to a receiving antenna of moderate size. *III* is an untuned circuit containing a detector connected to a galvanometer or to a pair of head telephones, as the circumstances of the work required. The electrolytic, perikon, and audion were used in circuit *III*, each being so coupled to circuit *II* as to give maximum effect. The magnetic detector was placed in circuit *II*, as it is generally used in the antenna. The Fleming vacuum valve detector was coupled to *II* by its own fixed coupling coils.

[vol. 2066] TABLE II—Electrolytic and Perikon detectors, shunted telephone method

	Relative sensitiveness	
	Strong signals	Weak signals
Electrolytic <sup>1</sup>	2.5	2.4
Perikon Electrolytic <sup>1</sup>	1.1	1.3
Perikon (0.2 volt)		
Electrolytic <sup>2</sup>	2.3	2.5
Perikon Electrolytic <sup>2</sup>	1.3	1.3
Perikon (0.2 volt)		

Telephone Resistance, 2100 Ohms

Electrolytic <sup>2</sup>	2.7
Perikon Electrolytic <sup>2</sup>	1.1
Perikon (0.2 volt)	

<sup>1</sup>Wollaston wire 0.0012 mm diam.

<sup>2</sup>Wollaston wire 0.0003 mm diam.

Telephone Resistance, 813 Ohms

Inductances, decrements, and wave lengths as in Table I.  $M_{12}$  adjusted for maximum sensitiveness.

### The Electrolytic Detector

Comparison was made of the sensitiveness of the electrolytic detector and the perikon, using a wave length of approximately 900 meters and a decrement of the waves given out by the exciter circuit, amounting to 0.16. The values of the inductances and capacities of the circuits were so chosen that they simulated the conditions of commercial work.

In Table II are given the ratio of sensitiveness for both strong and weak signals. The perikon was used without external EMF and also with about 0.2 of a volt applied in the direction of the rectification. Comparison was made by the shunted telephone method, the same telephones being used for both detectors. In one set of experiments the telephones used were of 2100 ohms and in another of 813 ohms. The relative sensitiveness of the two detectors was little affected by this change, showing that their effective resistances must be about the same. It is seen that without external EMF the perikon is less than half as sensitive as the electrolytic, but that when the 0.2 volt is applied the difference is very small. The electrolytic used in the experiment was of the free-wire type and two positive Wollaston wires were used during the test, one 0.003 and one 0.0012 mm in diameter. This was done because it has been frequently stated that the finer wire was more sensitive to weak signals. No marked difference between the two, however, could be detected. This shows that it is only necessary for sensitiveness, that the capacity reactance for the given frequency should be large, and that beyond a certain limiting diameter there is no object in reducing the size of the positive wire.

Table III shows the relation between galvanometer deflections with the thermoelement in circuit *II* and the intensity of signals in the electrolytic in circuit *III* as measured by the shunted telephone method.<sup>1</sup> This shows that the responses of the electrolytic as indicated by

<sup>1</sup> A comparison was also made of the sensitiveness of the perikon without external EMF and the electrolytic at the Washington Navy-Yard wireless station using incoming signals from a distant station. The results agreed within a few per cent with those found in the laboratory.

the telephone are proportional to the square of the oscillatory current.<sup>5</sup>

TABLE III. Electrolytic, received energy, and audibility of signals

Thermoclement in circuit II D	Electrolytic in circuit III	Ratio
3 3	12	36
5 6	22 4	40
3 4	140	41
6 3	250	40
8 0	324	41
17 0	645	38

Inductances, decrements, and wave length as in table I.  
 $M_{33}=0.025$ .

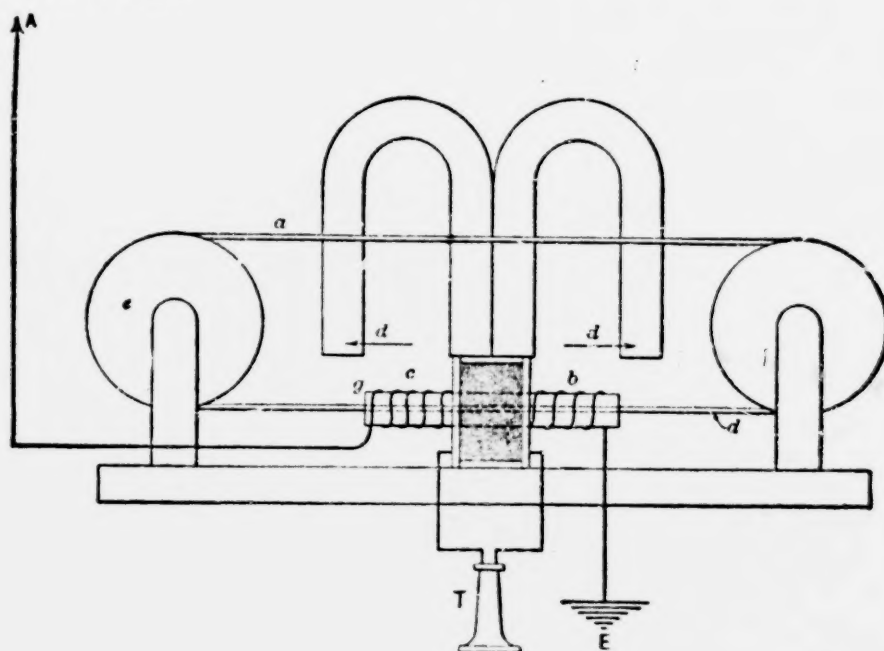


FIG. 4.

#### The Magnetic Detector. (Fig. 4)

The circuits for the comparison of the magnetic and perikon detectors are shown in fig. 2. The magnetic detector was connected directly in circuit II since it is usually used in the antenna. The magnetic detector used was of the ordinary commercial type, the D.C. resistance of the oscillatory coil being 9.7 ohms and the telephone coil 120 ohms. The

<sup>5</sup> Very strong signals, i.e., more than about 300 times audibility, sometimes give irregular results.

[fol. 2968] telephones furnished with the magnetic detector and used in the experiments had a resistance of 168 ohms. The telephones used with the perikon were of 1,200 ohms resistance and medium sensitiveness. For the comparison of sensitiveness the variable coupling method was used, the coupling  $L_1$  and  $L_2$  being changed until the signals became inaudible. When the readings on the magnetic were being taken the circuit containing the perikon was removed, then for the perikon readings the magnetic was cut out and the coupling  $L_1$   $L_2$  regulated for maximum strength of signals. The relative strength of signals for the different degrees of coupling between  $L_1$  and  $L_2$  was determined by means of the deflection of a galvanometer attached to the perikon. Such a series of readings is shown in table IV.

TABLE IV. Relative energy in circuit II for different distances  $d_{12}$  between  $L_1$  and  $L_2$  (see fig. 2)

$d_{12}$	Perikon D
10 cm	100
12	245
14	172
16	115
18	75
20	54
24	30
28	14
32	8
38	3

$$\lambda = 9000 \text{ m}$$

$$\bar{z}_1 = 0.16$$

With waves from the buzzer circuit having a damping of 0.16 and a wave length of about 9000 meters, it was found that the magnetic detector required 2.1 times as much energy to produce audible sound as the perikon used without external LMF.

Further experiments showed that by putting a 0.05 microfarad condenser in series with the telephone of the magnetic, thus tuning it roughly to the rate of the buzzer, the loudness of signals could be increased so that there was very little difference between it and the perikon.

TABLE V. Magnetic and Perikon Detectors, Weak Signals

$\lambda$	Ratio of sensitiveness	
	Magnetic	Perikon
3700 m	0.22	
9000	0.9	
20000	1.0	
30000	1.5	

Comparisons were also made at a wave length of 350 meters and at 2000 and 3000 meters. At 3000 meters the magnetic with tuned telephone was approximately one and [fol. 2969] one-half times as sensitive as the perikon. At 2000 there was very little difference, while at 350 meters the perikon was nearly five times as sensitive as the magnetic.

In order to explain these differences in relative sensitiveness, the logarithmic decrement of the circuit containing the magnetic was determined for different frequencies. For the purpose the circuits were those shown in Fig. 2, the magnetic detector being in its place in circuit *II* and the perikon with its galvanometer in the untuned circuit *III*, very loosely coupled to *II*, so that no appreciable energy was taken up by it. The buzzer exciter circuit was adjusted so as to give feebly damped oscillations having a decrement of about 0.02. The decrement of circuit *II* was determined from the well-known formula

$$\delta_I + \delta_{II} = \pi \frac{C_m - C}{C_m} \frac{I^2}{I_m^2 - I^2}$$

where  $C_m$  represents the reading of the condenser in circuit *II* for resonance and  $C$  any other reading slightly removed from resonance.  $I_m$  then represents the value of the oscillatory current for resonance and  $I$  that for the setting of the condenser at  $C$ . This formula becomes much more convenient in practice if we choose  $I^2$  so that it is just one-half  $I_m^2$ , for then the expression under the radical reduces to unity. As the deflection of the galvanometer connected to the perikon is proportional to  $I^2$ , our expression becomes

$$\delta_I + \delta_{II} = \pi \frac{C_m - C}{C_m}$$

where the change from  $C_m$  to  $C$ , either an increase or a decrease, is just sufficient to reduce the deflection of the galvanometer to one-half. The mean of several determinations of  $C_m - C$  gives as accurate values for the decrement as can be obtained from a curve plotted in the usual manner and calculated according to the complete formula. In damping experiments it is necessary that all the couplings be made so loose that any further loosening will not decrease the value of the damping.

TABLE VI Effective resistance of magnetic detector at different wave lengths

$\lambda$	$R'$
350 m	110 ohms
900	32
3000	10

TABLE VII Received energy and audibility of signals in magnetic detector

Perikon D	Magnetic A
300 mm	120
90	53
50	40
20.5	16.5
7.5	10
2.0	2

[Vol. 2976]  $\mathcal{Z}'$  having been previously measured, the effective resistance  $R'$  of the circuit containing the magnetic detector was calculated from the formula

$$R' = \frac{1}{2nL\mathcal{Z}_n}$$

where  $\mathcal{Z}_n$  is the decrement,  $n$  the frequency, and  $L$  the inductance of the circuit. After subtracting the known ohmic high frequency resistance of the circuit, the other losses due to the detector for the different frequencies are shown in Table VI. This table would indicate that the amount of iron and the number of turns of the oscillatory circuit of the magnetic detector should be varied according to the frequency for which it is to be used.

In Table VII is shown the relation between loudness of signal as determined by the shunted telephone method in the magnetic and the oscillatory energy passing through it as determined by the deflections of the perikon galvanometer. It is seen that the loudness of signal in the telephone attached to the magnetic is not proportional to the square of the oscillatory current, but corresponds more nearly to the 1.4 power.

#### The Fleming Vacuum Valve Detector. (Fig. 5)

The vacuum valve detector furnished for the test was constructed with fixed coupling coils inclosed in its case, so that it was found impossible to test it fairly at any except very short wave lengths without taking it completely to pieces.

The circuits were arranged as shown in Fig. 2, the vacuum valve being coupled by its own coils to circuit *II*. Signals were taken alternately on the perikon, adjusted for maximum strength of signal, and on the vacuum detector, one

detector circuit being removed when the other was in action. At a wave length of 350 meters and with a decrement of the incoming signals of 0.16, the ratio of sensitiveness of the perikon to that of the vacuum detector, as determined by the variable coupling method, was almost exactly two to one. For a wave length of 900 meters the perikon appeared to be at least ten times as sensitive as the vacuum valve. As there is no reason to believe that the vacuum detector would change its sensitiveness with frequency, this difference is almost certainly due to insufficient coupling." [fol. 2971] In Table VIII is given the relation between oscillatory energy in the main circuit and the audibility of signals in the telephone of the vacuum detector, as determined by the shunted telephone method. The audibility is seen to be proportional to the energy. The telephones furnished with the vacuum detector had a resistance of 8300 ohms and were connected by means of a step-in transformer to the detector circuit.

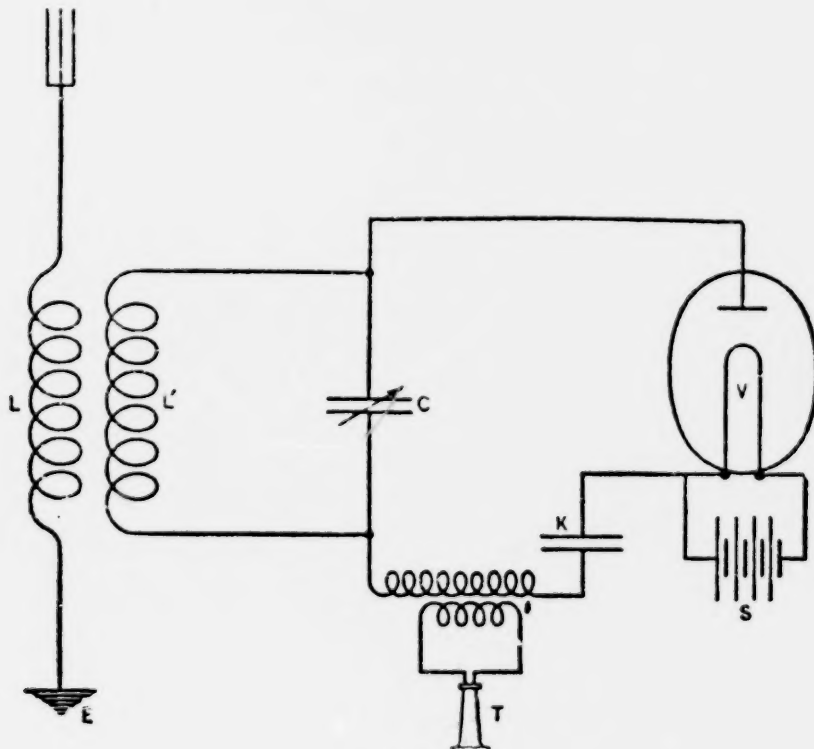


Fig. 5.

\* This shows the disadvantage of constructing receiving apparatus with fixed coupling.

TABLE VIII. — *Received energy and audibility of signals in Fleming vacuum detector*

Perikon	Vacuum detector
10	A
43	38
21	20
10	9
5	5

## The Audion. (Fig. 6)

The De Forest form of vacuum detector, called by him the audion, is shown diagrammatically in Fig. 6. Here *V* is an exhausted glass bulb containing a tantalum filament *F*, heated by three storage cells *S*, a metal plate *P* and a metal grid *G* between the filament and the plate. The filament and plate are connected externally through a battery *B*

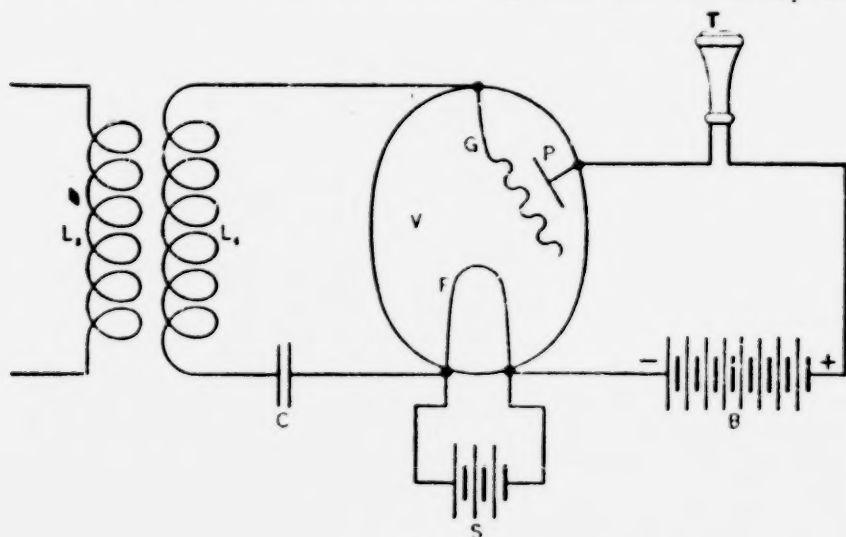


FIG. 6.

[vol. 2972] of 36 small cells, any number of which can be thrown into the circuit, and a pair of head telephones of about 1200 ohms resistance. The filament and grid are connected through a small fixed condenser *C* and an inductance *L*, which is coupled to the oscillatory circuit.

The action of the detector appears to be as follows: The heated filament *F* is charged negatively by the battery *B* and a steady stream of negative electrons flows from the hot filament to the cold plate producing a direct current through the telephone. When an oscillatory electromotive force is impressed on the circuit *F L G*, the negative current can flow from *F* to *G* inside the bulb and not in the reverse direction, just as in the Fleming detector. The grid *G* thus

becomes negatively charged and as it lies between  $F$  and  $P$  the direct current through the telephone is decreased as may be shown by placing a galvanometer in the telephone circuit.

The sensitiveness of the audion was compared with that of the electrolytic already described by the varying coupling method. (See Fig. 2.) Here  $L_3$  and  $L_4$  were the primary and secondary of a Wireless Specialty Apparatus Company tuner, the secondary condenser of the tuner being detached. The detectors were introduced alternately in circuit  $III$  and their most favorable conditions of coupling were determined separately. The audion, having a higher resistance, required a stronger coupling. The same telephones (1200 ohms) were used for both detectors, previous tests having shown that they were suited to each. High-resistance telephones up to 8000 ohms were tried with the audion, but were found to be less satisfactory than the ones used. This is remarkable, as with the Fleming vacuum detector 8000-ohm telephones are used and even then the current is stepped down through a transformer.

[fol. 2973] Below are given the data of the experiment:

$\lambda=900$  m.,  $\beta_1=0.3$ ,  $L_1=0.062$ ,  $L_2=0.03$ ,  $L_3=0.705$ ,  $L_4=0.92$  m. h. (electrolytic).  $L_4=2.3$  (audion).

Electrolytic coupling  $L_3$   $L_4=7$  cm on coupling scale<sup>7</sup> of tuner; audion coupling  $=2$  cm. Distance between coils  $L_3$   $L_4$  for least audible signal, 20.5 cm (electrolytic); 23 cm (audion).

Ratio of energy sensitiveness  $\frac{\text{audion}}{\text{electrolytic}}=1.5$ . Some of the bulbs were slightly more sensitive than this when first tried, but the sensibility decreased with use.

The law governing the relations between the intensity of the oscillations and the loudness of response in the telephone, as determined by the shunted telephone method, seems to depend on the impressed direct electromotive force from the battery  $B$  and also on the temperature of the filament  $F$ , as would be expected from the known form of the current voltage curve in the case of the passage of electricity from a hot to a cold body through a gas. For most adjustments the response of the telephone is apparently nearly proportional to the square of the oscillatory current.

<sup>7</sup> The numbers on the scale represent the distance the two coils are drawn apart from the position of maximum mutual inductance.

In addition to the above detectors, a very large number of other types have been tested in the laboratory, among which are the tellurium, silicon, and carbon already described,\* and also many crystal detectors. These detectors are all of the rectifying type and are remarkable in that when properly adjusted and used with telephones of proper resistance, and in some cases with small EMF in the direction of the rectification, they all give practically the same sensibility as the perikon. The usefulness of several of these is, however, limited by the difficulty of adjustment and a lack of constancy. In most of these detectors the loudness of the signal increases nearly in proportion to the square of the oscillating current, although in some of them the increase in loudness is less rapid.

United States Naval Wireless Telegraphic Laboratory,  
March 1, 1910.

#### DEFENDANT'S EXHIBIT G-1

##### *Practical Wireless Telegraphy, by Bachar, 1918*

Like the carborundum detector, the Fleming valve has a rising characteristic and when an E. M. F. is applied to the space between the plate and the filament the current may be adjusted to the critical point on the characteristic curve so that the addition of a slight antenna voltage causes a large increase of the local battery current flowing through the head telephones.

A satisfactory diagram appears in Fig. 162 wherein a potentiometer P-1 is shunted across the filament battery and a portion of the current flows through the head telephones and the detector. With this arrangement of circuits advantage is taken of the particular voltampere characteristic of the valve and a relay action due to a local [fol. 2974] source of energy is obtained. For the maximum strength of signals with this circuit it is necessary to adjust the position of the sliding contact on the potentiometer as well as the incandescence of the filament, until the desired results are obtained.

The diagram, Fig. 162, shows the fundamental circuit of the widely used *Marconi-Fleming valve receiver*. The *open circuit* comprises:

\* This Bulletin, Vol. 5, No. 1, p. 133; 1908.

- (1) The aerial tuning inductance L-1,
- (2) The short wave condenser C-1,
- (3) The primary winding L-2,
- (4) The shunt impedance R-1,
- (5) The change-over switch S-1, S-2, S-3.

The *intermediate circuit* comprises:

- (1) The winding L-3 in inductive relation to L-2,
- (2) The winding L-4 in inductive relation to L-5,
- (3) The variable condenser C-2.

The *secondary circuit* comprises:

- (1) The secondary winding L-5,
- (2) The billi condenser C-3,
- (3) The Fleming valve F, P,
- (4) The battery B (or four volts generally),
- (5) The 10 ohm rheostat R,
- (6) The 400 ohm potentiometer P-1,
- (7) The fixed condenser C-4,
- (8) The head telephone P-2.

Inductances L-2, L-3, L-4, L-5, L-6 are of fixed value, but L-1 is variable through the medium of a multi-point switch.

When the D. T. three blade switch S-1 is thrown to the right, primary winding L-2 is connected in series with the *aerial circuit* which brings the *intermediate circuit* into use, but the switch, thrown in the opposite direction, disconnects L-2 and connects L-6 in series with the aerial. L-6 being wound tightly about the turns of L-5, the open and closed circuits are closely coupled. *This*

*increases the damping of the receiving system* and makes the set responsive to waves of different length at one set

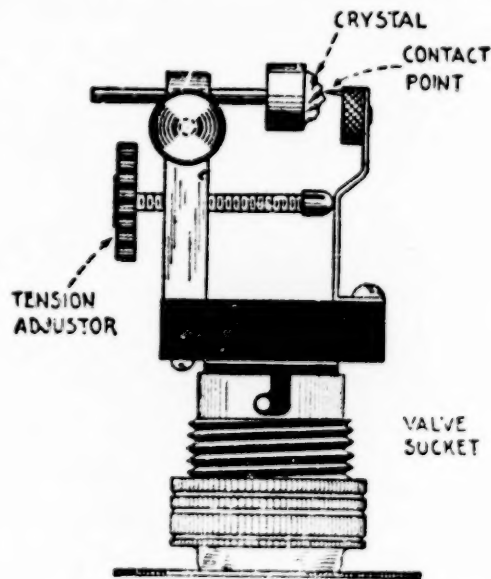


FIG. 163. Carborundum Crystal Holder to Fit Fleming Valve Socket.

of adjustments, but, of course, does not give the strength of signals that can be obtained by resonant adjustments.

The position of the switch corresponding to "*close coupling*" is marked "Stdby," an abbreviation for the word [fol. 2975] "*standby*." The switch is placed in this position when a particular receiving station awaits a call from one of several sending stations which are not exactly tuned to the same wave length.

In the opposite position, the changeover switch is marked "*tune*" and with the circuits of this connection, sharp resonant adjustments can be obtained. The wave length of the *intermediate circuit* is increased or decreased by the variable condenser C-2 only and similarly the wave length

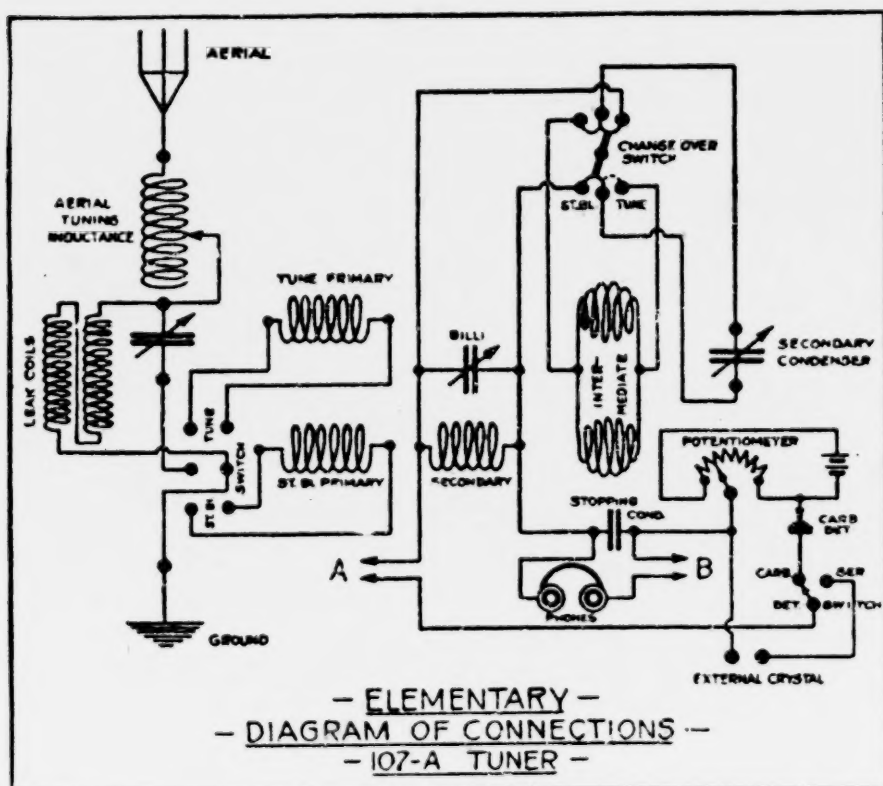


FIG. 164 - Complete Circuits of Type 107a Tuner (American Marconi Company).

of the secondary or detector circuit, by the condenser C-3.

The coupling between the inductances of the intermediate circuit and inductively related coils is varied simultaneously by means of a shaft (and knob) upon which both coils, L-3 and L-4, are mounted.



the D.P.D.T. switch is thrown to the "standby" position and the intermediate circuit cut out. For wave lengths below 1,000 meters either the "standby" or "tune" circuits can be employed at the discretion of the operator.

It is to be noted, although the 107-a tuner is designed for the carborundum detector, an extra set of posts is provided for an additional crystal such as *citrinite*. When the latter detector is employed, the potentiometer is out of the circuit. Observance next should be made of the binding posts from which wires are connected to the receiver circuits and to the contacts of an aerial change-over switch. The latter, when open, protect the detector and head telephones from the induced potentials of the local transmitter. [fol. 2977] In the diagram, Fig. 165-b, L-1 is the aerial tuning inductance, the value of which is altered by means of a multi point switch mounted on the left hand front of the tuner.

C-1 is the short wave variable condenser connected in series with the aerial system. In the full scale position it short circuits itself and is thus cut out of the antenna circuit. This condenser is mounted on the left hand side on the top of the tuner.

L-2 is the primary winding of the receiving tuner and has a fixed value of inductance (not variable).

The complete circuit for this connection is indicated in Fig. 165a. Note carefully that the intermediate circuit is *not* employed. It is important to note also that the type

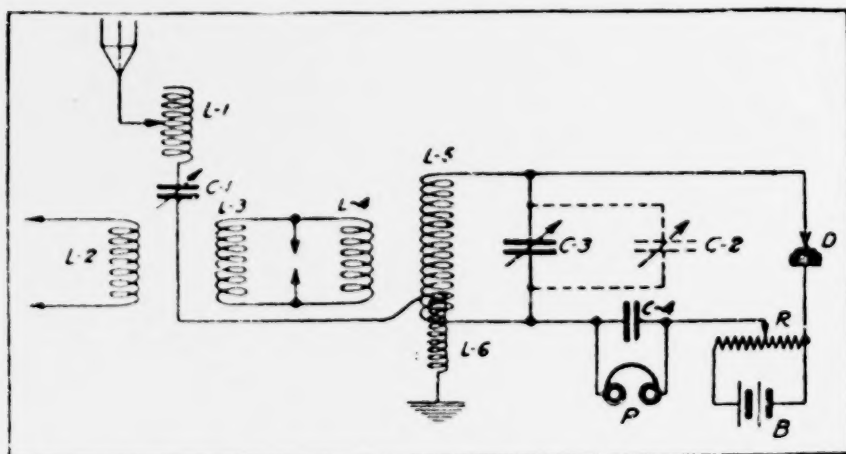


FIG. 165a. "Tune" Circuits of Type 107a Tuner.

107-a tuner is fitted with four binding posts (at the rear) from which connections extend to the type S aerial change-over switch. When the antenna switch is placed in the transmitting position, the circuits of the 107-a tuner are interrupted at the points A and B (Fig. 165b), thus breaking the circuit to the detector and the head telephones. The contacts at this switch must have careful inspection from time to time, for, unless they close properly, the apparatus positively will not function.

Should these contacts be broken, a permanent jumper should be placed across the binding posts to keep the circuit closed.

Type 107-a tuner should be used with the type S or type I aerial changeover switches only.

The complete circuits for the tuner are shown in detail in Fig. 165a and with the foregoing explanation, the functions of the various elements should be clear without further instruction.

(c) *General Instructions.*—For “stand-by” tuning or broad adjustment at wave lengths up to 1,000 meters (see Fig. 165c), place the double throw knife switch to the left.

Set the condenser switch on “tune.” Set the coupling knob at zero. Carefully adjust the billi condenser. Connect in a few points of the aerial tuning inductance. Vary the capacity of the short wave condenser.

For long wave lengths (in excess of 1,000 meters) place the condenser switch on “stand-by long wave” position. Vary carefully the capacity of the intermediate condenser. Add inductance at the aerial tuning inductance.

For sharp tuning on the shorter wave lengths (below 1,000 meters), place the double throw knife switch to the “tune” position. Place the condenser switch on the “tune” position. Set the coupling knob at from 70° to 90°. Adjust carefully the intermediate condenser. Add two or three points of inductance at the aerial tuning inductance. Follow this by variation of the capacity of the short wave condenser. In this position, all the variable elements of the complete tuner are in use.

137. *Marconi Magnetic Detector and the Multiple Tuner Circuits (English Marconi Companion).*—The magnetic detector shown diagrammatically in Fig. 167 is an oscillation

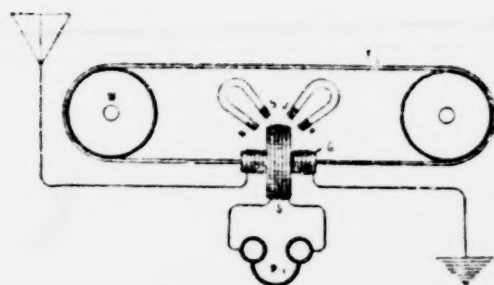


FIG. 167. Marconi's Magnetic Detector.

detector of unvarying stability. A description of the detector and an explanation of its functioning follow:

A continuous band made up of a group of fine iron wires revolves on the chony grooved wheels W which are

turned by clockwork in the base of the instrument. The band passes through the glass tube G, which has a small single layer of fine wire comprising 6 to 10 turns through which the radio frequent oscillations flow. Directly over this winding is placed the small bobbin of wire S which has approximately the resistance of the head telephones P-1. Two horseshoe permanent magnets with like poles adjacent are mounted immediately above the tube and near to it. Some argument exists concerning the action of this detector during the reception of signals but it is sufficient to say that when the iron band passes underneath the two permanent magnets it undergoes a cyclic change in magnetism and is extremely sensitive to an impressed external magnetic field such as that generated by a radio ~~frequency~~ current flowing through the winding G.

When electrical oscillations induced in a receiver aerial by a distant transmitter pass through the winding P, one complete group of oscillations sets up an alternating magnetic field which causes a single movement or a change in the position of the flux in the iron band. The bobbin S being in the path of the flux, it is acted upon inductively, a current being induced in the windings which flows through the head telephone creating a single sound for each group of incoming oscillations. The note of the transmitter is faithfully reproduced, because each group of oscillations radiated by [fol. 2979] the transmitter has a cumulative effect on the change of flux in the iron band, which causes a single movement of the telephone diaphragm. Although the magnet detector lacks the sensitiveness of the crystal

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It has frequently been observed that the magnetic detector gives better response to 500 cycle transmitters when the iron band revolves at a speed about twice that used in receiving from 60 cycle transmitters. Normally the band travels at a very low speed—a few feet per minute.

138. *The Marconi Type 106 Receiving Tuner.* (*American Marconi Company*).—A receiving set of particular excellence combining mechanical and electrical features of merit is the type 106 tuner of the American Marconi Company. This set is of the panel type, the necessary controlling switches being mounted on the front of the board as shown in photograph 170, the coupler, variable condensers, potentiometer, etc., being mounted on the rear as in photograph 171. The *coupling* between the primary and secondary windings is varied by means of a special *rack and pinion adjustment* which is in turn controlled by a knob on the front of the panel with a scale marked from zero to 10 (marked "coupling").

The switch marked "*transformer secondary*" and the control handle marked "*secondary condenser*" control the inductance and capacity of the secondary circuit. The wave length adjustment of the circuit can be increased by turning the switch or the knob of the condenser counter clockwise. Different values of inductance and capacity can be employed in this circuit while holding the same wave length. This changes the damping of the circuit and proper proportioning (of inductance and capacity) may give increased strength of signals during the reception of signals from certain stations.

The control handle marked "*potentiometer*" varies the flow of current through the detector crystal. Close adjustment of the potentiometer is necessary when the incoming signals are comparatively weak. The switch marked "*battery*" turns the local battery current on and off.

The terminals marked "*battery*" connect to four dry cells in a separate box and the terminals marked "*telephones*" are the binding posts for connection to 2,000 ohm receivers.

As the transmitter operates at approximately the wave length to which the secondary circuit of the receiver is adjusted, it produces exceedingly strong signals which are liable to impair the sensitive condition of the crystal. To obviate this, connections are made with the antenna switch so that when the antenna switch is in the transmitting position the terminals of the detector and the secondary condenser are short-circuited. Care should be taken to see that the antenna switch, with which this receiver is to be used, is so constructed as to perform the above operations. If [fol. 2980] this is done, the transmitter has very little or no effect on the sensitiveness of the crystal and it will, therefore, be in a sensitive condition for receiving immediately after transmission. (See diagrams, Figs. 201, 202 and 203.) In addition to paragraph 130 the student should read the general instructions in paragraph 156a.

139 *Marconi Receiving Tuner Type 101 (American Marconi Company).*—The type 101 receiver consists of an inductively coupled transformer with two solid rectifier detectors and the necessary accessory apparatus mounted on a hard rubber panel and enclosed in a mahogany case. The front elevation of this set is shown in photograph, Fig. 173, the rear elevation in Fig. 174, and a fundamental diagram in Fig. 175.

The aerial is connected to the binding post "antenna" and the earth connection is made to the binding post marked "ground." The circuit between these two points is adjusted to resonance with the incoming signal by variation of the two transformer primary switches, the primary loading coil switch, the primary condenser, and the primary condenser switch which is marked "out" "Series" and "shunt." The purpose of this switch is to connect the primary condenser in series or in parallel to the aerial or to disconnect the condenser entirely.

Placing the primary condenser switch in the "Shunt" position increases the wave length of the aerial circuit corresponding to any given setting of the inductance switches. This may be done at any time instead of increasing the inductance. Generally speaking, the method of varying inductance is preferable and gives a louder response, but in

exceptional cases the reverse is true and in any particular case a trial of the two methods can be made to find out which is the better. The best secondary setting for maximum response to any particular wave length is that of maximum inductance and minimum capacity, but the greatest selectivity will be obtained with smaller inductance and greater capacity.

When the carborundum detector is in use it will be necessary to adjust the potentiometer to a point which gives the greatest sensitiveness.

It should be noted that when using the Cernusite detector during the reception of very weak signals the potentiometer should always be in zero position, but for signals of moderate intensity it does not matter particularly what position this may happen to be in. In order that the operator may be able to measure approximately the wave length of the incoming signals, calibrations of the secondary are given with each tuner, it being understood that these are correct only when the secondary is coupled very loosely to the primary.

With the 101 receiver are supplied adjustable head telephones which are tuned to the group frequency of the transmitter. Also the electrical circuit through the telephones and the stopping condenser is tuned to the same group frequency.

[fol. 2981] It is advisable occasionally to insert a piece of paper between the spark points of the antenna and ground binding posts and telephone binding posts to make sure they are not short-circuited.

140. *The Marconi Universal Receiving Set (English Marconi Company).*—The complete circuits of the Universal Crystal Receiver are indicated in the diagram, Fig. 176, and a photograph of the finished instrument in Fig. 177, the tuner having been designed for wave lengths between 300 and 3,000 meters. The circuits are applicable to all types of crystal rectifiers, particularly those of carborundum, zincite, bornite, etc.

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The usual aerial tuning inductance is represented at L 1, the short wave condenser at C-1, and the primary winding of the *tuning transformer* at L 2. L 2 has three tapings,

which are varied by means of the switch. The secondary circuit of the receiving tuner is divided into three units, the following range of wave lengths being obtained with each: L-5 has the correct values for all wave lengths up to 600 meters; L-4 for waves between 600 and 1,600 meters, and L-3 for waves between 1,000 and 3,000 meters. The necessary change of inductance is obtained by the wave length changing switch D, which completely disconnects the unused turns from the circuit.

154. *The Marconi Balanced Crystal Receiver (English Marconi Company).*—No apparatus or circuit has so far been devised to completely eliminate the interference of static discharges. However, communication can be effected by the circuits of the Marconi balanced crystal receiver

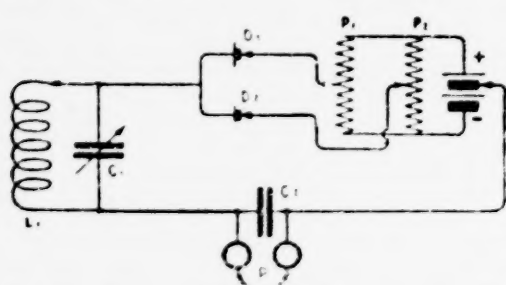


FIG. 198. Circuits of Marconi's Balanced Crystal Receiver. (English Marconi Company.)

when with ordinary circuits it would not be possible. In fact, the balanced crystal tuner often reduces the interference from this source to a marked degree.

The complete circuits of the balanced crystal receiver are shown in the diagram, Fig. 198, where the secondary winding of the receiving tuner is represented by the coil L-1, the secondary condenser at C-1, the opposed crystals at D-1 and D-2, the potentiometer at P-1 and P-2, the battery at B and the telephones at P.

To carry out the fundamental principle of this receiver, crystals D-1 and D-2 must have like volt-ampere characteristics, and, accordingly, crystals are especially selected for the purpose.

Briefly, the action of this circuit can be described as follows: If crystals D-1 and D-2 are adjusted to the same degree of sensitiveness their currents will act equally and oppositely upon the telephone P, and no signals will result. If, however, D-2, let us say, is adjusted to a high degree of [fol. 2982] sensitiveness and D-1 to a lesser degree, signals will be received.

Under these conditions, if an extra severe discharge of static excites the aerial circuit, almost equal effects are

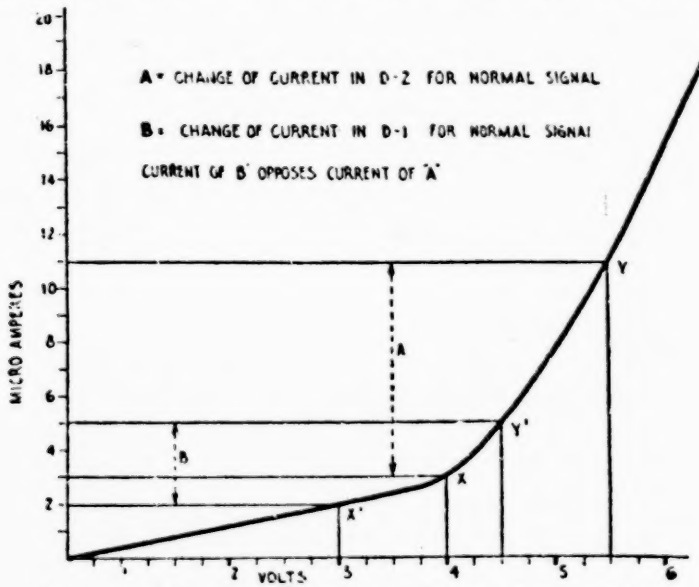


FIG. 199.—Curve Showing Principle of Balanced Crystal Receiver.

produced in the head telephone P by both crystals, and the crashing sounds ordinarily experienced are partially eliminated.

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steel bar F closes the circuit to the primary winding of the power transformer through the contacts 11 and 12. In the opposite position the bar separates the spring contacts M, M' 200-a, which disconnects the transmitting oscillation transformer from the aerial during the period of reception, preventing the incoming oscillations leaking to earth. *The various circuits closed by the discs mounted on the hard rubber rod place the detector and head telephone on short circuit during the period of transmission. They may also be employed to start and stop a motor blower or an automatic motor starter. The type I switch is supplied with Marconi transmitting sets up to 5 K.W. capacity.*

For the use of operators in the Marconi service, the circuit diagrams, Figs. 201, 202, and 203, are published, showing the connections in Fig. 201 of the type I antenna switch to the external binding posts of the type 106 receiving tuner, and in Fig. 202 the connections of the type S, H, aerial changeover switch to the external binding posts of the type 106 tuner. The diagram, Fig. 203, shows the connections

of the type I antenna switch to the external binding posts of the type 107-a receiving tuner.

[fol. 2983] In the diagram, Fig. 201, binding posts 2, 4, and 5 of the type I antenna switch short circuit the crystal

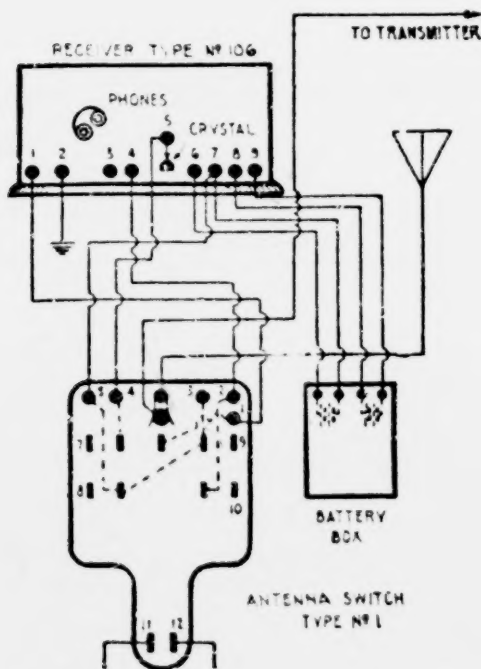


FIG. 201. Type I Switch Connected to Type 106 Receiving Tuner.

detector and the head telephones during transmission. Binding post No. 1 connects to aerial binding post No. 1 of the type 106 tuner. Contacts 11 and 12 close the circuit to the primary winding of the transformer. The binding posts 6, 7, 8, and 9 of the type 106 tuner are connected to the four binding posts of the battery box as shown.

In the diagram, Fig. 202, posts 1, 2, 4 and 5 of the type S. H. antenna switch lead to contacts which place the head telephone and detector of the type

106 tuner on short circuit. Binding posts 11 and 12 close the circuit to the primary winding of the transformer.

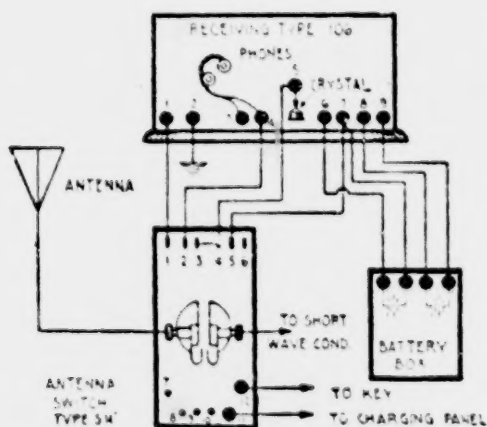


FIG. 202. Type S. H. Switch Connected to Type 106 Receiving Tuner.

In the diagram, Fig. 203, posts 2, 4, and 5 of the type I switch lead to contacts which short circuit the receiving detector and the receiving telephones. These diagrams should be carefully studied and in event that the wiring is taken down, the connections shown should be carefully duplicated.

156. *Type 112 Receiving Tuner.*—This receiving tuner was primarily de-

signed for use with the special  $\frac{1}{4}$  K.W. cargo type transmitter developed by the Marconi Company and fundamentally is similar to the type 101 and type 106 tuner, but the construction is considerably simplified. A front view is shown in Fig. 203-a and a side view in Fig. 203-b.

As will be seen in the wiring diagram, Fig. 203-e, the circuits are similar to those shown in Fig. 153-b, the potentiometer, battery, and head phones being shunted.

[fol. 2984]

#### DEFENDANT'S EXHIBIT H-1

*Proceedings of Institute of Radio Engineers, August 1916*

The receiver used with these sets is of the coupled circuit type and is known as the type "106" receiver. There are two circuits in this receiver, the one circuit known as the open or antenna circuit, and the other as the closed tuned circuit. These two circuits are coupled inductively and means are provided for varying the inductive relation of the two circuits. The primary circuit consists of the antenna, a loading coil, a primary coil, a series condenser, and a ground connection, all being connected in series. By means of a switch any amount of the loading coil in the primary can be thrown into circuit at will. This enables the operator to adjust readily this circuit to the received signals. In case the wave length of the received signal is shorter than the natural period of the antenna, the series condenser is thrown in the circuit which brings this circuit to the desired period. The secondary circuit consists of a secondary coil or inductance which is movable with respect to the primary. This coil is in series with a variable condenser. A switch is provided which permits any amount of the secondary to be thrown in the circuit. The variable condenser permits the variation of the capacity of this circuit so that it may be adjusted for resonance with the primary circuit. By having both the inductance and capacity of this circuit variable, the ratio of capacity to inductance can be varied while keeping the period of the circuit constant. This enables the operator to obtain the best adjustment for operating the detector. The detector used in this receiver is of the crystal type. A battery and potentiometer are provided so that a crystal can be operated either with or without battery as desired. The detector circuit consists of the potentiometer, a stopping condenser and the telephones. The

potentiometer and stopping condenser are connected in series with each other and in shunt to the variable condenser. The telephones are connected in shunt with the stopping condenser. A test circuit is provided which enables the operator to excite the antenna circuit at will so that he can adjust the detector for maximum sensitiveness. These circuits are all shown in Figure 4. A careful consideration of this drawing will enable the reader to understand fully the complete circuits of both transmitter and receiver.

PARLIAMENTARY PAPERS 1-1

PROCEEDINGS

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*From December 5, 1889, to April 24, 1890.*

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families are also comparatively few. The families so contributing are, however, among the most important and widely distributed in the vegetable kingdom; as also are some of the plants they contribute. As prominent examples may be mentioned, the *Gramineæ*, affording the cereal grains, a large proportion of the mixed herbage of grass-land, and other products; also the *Leguminosæ*, yielding pulse crops, many useful herbage plants, and numerous other products. As we have said, there does not seem to be an unsolved problem as to the sources of the nitrogen of other of our agricultural plants than those of the leguminous family. Obviously, however, it would be unsafe to generalise in regard to individual families as a whole, from results relating to a limited number of examples supplied by their agricultural representatives alone. Still, there is nothing in the evidence at present at command, to point to the supposition that there is any fundamental difference in the source of the nitrogen of different members of the same family, such as is clearly indicated between the representatives of the leguminous, and of the other families, supplying staple agricultural products. On the other hand, existing evidence does not afford any means of judging whether or not similar, or allied agencies to those now under consideration, or even quite different ones, may come into play in the nitrogen assimilation of the members of other families which contribute such a vast variety of vegetation to the earth's surface.

We have pleasure in stating that the conduct of the investigation has largely devolved upon Dr. N. H. J. Miller. He has been almost wholly responsible for the analytical work, as well as for the photographing, by which a permanent record, not only of the above-ground growth, but of the root-development of the experimental plants has been secured. It should be added, that Mr. J. J. Willis has materially assisted in the observation and noting on growth; also in the separation of the roots, mounting them for observation and for photographing, and in noting upon them.

- II. "On Electric Discharge between Electrodes at different Temperatures in Air and in High Vacuum." By J. A. FLEMING, M.A., D.Sc., Professor of Electrical Engineering in University College, London. Communicated by Professor G. C. FOSTER, F.R.S. Received December 16, 1889.

(Preliminary Notice.)

It has been known for some time that if a platinum plate or wire is sealed through the glass bulb of an ordinary carbon filament incandescent lamp, this metallic plate being quite out of contact with



the carbon conductor, a sensitive galvanometer connected between this insulated metal plate enclosed in the vacuum and the external *positive* electrode of the lamp indicates a current of some milli-ampères passing through it when the lamp is set in action, but the same instrument when connected between the *negative* electrode of the lamp and the insulated metal plate indicates no sensible current. This phenomenon in carbon incandescence lamps was first observed by Mr. Edison, in 1884, and further examined by Mr. W. H. Preece, in 1885.\* The primary object of the experiments described in this paper was the further examination of this effect, but the inquiry has extended itself beyond this range and embraced some general phenomena of electric discharge between electrodes at unequal temperatures, and in particular has revealed some curious effects in the behaviour of an electric arc taken between carbon poles towards a third insulated carbon or metal poles.

The first series of experiments had reference to the nature of the effect observed in the incandescence lamps having an insulated wire or plate placed in the vacuum.

If a platinum wire is sealed through the glass bulb of an ordinary carbon filament lamp and carries at its extremity a metal plate, so placed as to stand up between the legs of the carbon horseshoe without touching either of them, then when the lamp is actuated by a continuous current it is found that:—

(1.) This insulated metal plate is brought down instantly to the potential of the base of the negative leg of the carbon, and no sensible potential difference exists between the insulated metal plate and the negative electrode of the lamps, whether the test be made by a galvanometer, by an electrostatic voltmeter, or by a condenser.

(2.) The potential difference of the plate and the positive electrode of the lamp is exactly the same as the working potential difference of the lamp electrodes, provided this is measured electrostatically, *i.e.*, by a condenser, or by an electrostatic voltmeter taking no current.

\* See 'Roy. Soc. Proc.' vol. 38, 1885, p. 219. "On a Peculiar Behaviour of Glow Lamps when raised to High Incandescence."—In this paper Mr. Preece describes a very careful series of observations carried out with Edison incandescence lamps, and which cover the same ground as a portion of the experiments here described. The results given in (4), (7), and (11) confirm the facts which were first ascertained by him. He also arrived at the general conclusion that the phenomena so observed are due to an electric convection by matter projected from the incandescent carbon. By carrying up the working electromotive force of the lamp to a point productive of very high incandescence, he was able to measure the resulting current through a galvanometer connected between the positive lamp electrode and the middle plate corresponding to every degree of incandescence, and showed that, whilst increasing up to a certain point, the galvanometer current fell off rapidly soon after a certain critical temperature was reached, which corresponded to the appearance of a blue light or haze in the glass receiver.—[Jan. 14th, 1890.]

but if measured by a galvanometer the potential difference of the plate and the positive electrodes of the lamp is something less than that of the working lamp electrodes.

(3.) This absolute equality of potential between the negative electrode of the lamp and the insulated plate only exists when the carbon filament is in a state of vivid incandescence, and when the insulated plate is not more than an inch or so from the base of the negative leg. When the lamp is at intermediate stages of incandescence, or the plate is considerably removed from the base of the negative leg, then the plate is not brought down quite to the same potential as the negative electrode.

(4.) A galvanometer connected between the insulated plate and the positive electrode of the lamp shows a current increasing from zero to four or five milliamperes, as the carbon is raised to its state of commercial incandescence. There is not any current greater than 0.0001 of a milliampère between the plate and negative electrode when the lamp has a good vacuum.

(5.) If the lamp has a bad vacuum this inequality is destroyed, and a sensitive galvanometer shows a current flowing through it when connected between the middle plate and either the positive or negative electrode.

(6.) When the lamp is actuated by an *alternating* current a *continuous* current is found flowing through a galvanometer, connected between the insulated plate and *either* terminal of the lamp. The direction of the current through the galvanometer is such as to show that negative electricity is flowing from the plate through the galvanometer to the lamp terminal. This is also the case in (4); but, if the lamp has a bad vacuum, then negative electricity flows *from* the plate through the galvanometer to the positive terminal of the lamp, and negative electricity flows *to* the plate through the galvanometer from the negative terminal of the lamp.

(7.) The same effects exist on a reduced scale when the incandescent conductor is a platinum wire instead of carbon filament. The platinum wire has to be brought up very near to its point of fusion, in order to detect the effect, but it is found that a current flows between the positive electrode of a platinum wire lamp and a platinum plate placed in the vacuum near to the negative end of that wire.

(8.) The material of which the plate is made is without influence. Platinum, aluminium, and carbon have been indifferently employed.

(9.) The active agent in producing this effect is the *negative leg* of the carbon. If the negative leg of the carbon is covered up by enclosing it in a glass tube this procedure entirely, or nearly entirely, prevents the production of a current in a galvanometer connected between the middle plate and the positive terminal of the lamp.

(10.) It is a matter of indifference whether a glass or metal tube is

employed to cover up the negative leg of the carbon; in any case this shielding destroys the effect.

(11.) If, instead of shielding the negative leg of the carbon, a mica screen is interposed between the negative leg and the side of the middle plate which faces it, then the current produced in a galvanometer connected between the positive terminal of the lamp and the middle plate is much reduced. Hardly any effect under the same circumstances is produced when the mica screen is interposed on that side of the metal plate which faces the positive leg of the carbon.

(12.) The position of the metal plate has a great influence on the magnitude of the current traversing a galvanometer connected between the metal plate and the positive terminal of the lamp. The current is greatest when the insulated metal plate is as near as possible to the base of the negative leg of the carbon, and greatest of all when it is formed into a cylinder which embraces without touching the base of the negative leg.

The current becomes very small when the insulated metal plate is removed to 4 or 5 inches from the negative leg, and becomes practically zero when the metal plate is at the end of a tube forming part of the bulb, which tube has a bend at right angles in it. Copious experiments have been made with metal plates in all kinds of positions.

(13.) The galvanometer current is greatly influenced by the surface of the metal plate, being greatly reduced when the surface of the plate is made small, or when the plate is set edgewise to the negative leg, so as to present a very small apparent surface when seen from the negative leg. In a lamp having the usual commercial vacuum, the effect is extremely small when the insulated metal plate is placed at a distance of 18 inches from the negative leg, but even then it is just sensible to a very sensitive galvanometer.

(14.) If a charged condenser has one plate connected to the insulated metal plate, and the other plate connected to any point of the circuit of the incandescent filament, this condenser is instantly discharged if the positively charged side of the condenser is connected to the insulated plate, and the negative side to the hot filament. If, however, the negative leg of the carbon horseshoe is shielded by a glass tube, this discharging power is much reduced, or altogether removed.

(15.) If the middle plate consists of a separate carbon loop, which can itself be made incandescent by a separate insulated battery, then, when this middle carbon is rendered incandescent and employed as the metal plate in the above experiment, the condenser is discharged when the negatively charged side of it is connected to the hot middle carbon, the positively charged side of it being in connexion with the principal carbon horseshoe.

(16.) If this last form of lamp is employed as in (4) the subsidiary carbon loop being used as a middle plate, and a galvanometer being connected between it and either the positive or negative main terminal of the lamp, then when the subsidiary carbon loop is cold, we get a current through the galvanometer only when it is in connexion with the positive main terminal of the lamp, but when the subsidiary carbon is made incandescent by a separate insulated battery, we get a current through the galvanometer when it is connected either to the positive or to the negative terminal of the lamp. In the first case the current through the galvanometer is a negative current, flowing from the middle carbon to the positive main terminal, and in the second case it is a negative current, from the negative main terminal to the middle subsidiary hot carbon.

(17.) If a lamp having a metal middle plate held between the legs of the carbon loop has a galvanometer connected between the negative main terminal of the lamp and this middle plate, we find that when the carbon is incandescent there is no sensible current flowing through the galvanometer. The vacuous space between the middle plate and the hot negative leg of the carbon possesses, however, a curious unilateral conductivity. If a single Clark cell is inserted in series with the galvanometer, we find that this cell can send a current deflecting the galvanometer when its negative pole is in connexion with the negative main terminal of the lamp, but if its positive pole is in connexion with the negative terminal of the lamp, then no current flows. The cell is thus able to force a current through the vacuous space when the direction of the cell is such as to cause negative electricity to flow across the vacuous space from the hot carbon to the cooler metal plate, but not in the reverse direction.

(18.) If a vacuum tube is constructed, having at each end horse-shoe carbon filaments sealed into it, and which can each be made separately incandescent by an insulated battery, we find that such a vacuum tube, though requiring an electromotive force of many thousands of volts to force a current through it when the carbon loops are used as electrodes and are cold, will yet pass the current from a single Clark cell when the carbon loop which forms the negative electrode is rendered incandescent. It is thus found that a high vacuum terminated electrically by unequally heated carbon electrodes possesses an unilateral conductivity, and that electric discharge takes place freely through it under an electromotive force of a few volts when the negative electrode is made highly incandescent.

(19.) These experimental results above described led the writer to investigate, in the same manner, the electric arc between carbon poles taken in air. If an electric arc is formed, in the usual way, between carbon poles, and a third insulated carbon pole is allowed to dip into or touch the electric arc, or, better still, has the electric arc projected

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against it by a magnet, it is found that this third or insulated pole is brought down almost to the potential of the negative carbon of the arc, and that a galvanometer connected between the third insulated carbon and the negative carbon of the arc indicates no current, but that if joined up between the positive carbon and the middle carbon a strong current of about an ampère or so is found to be passing. If an electric bell or an incandescent lamp is joined up between the third carbon and the *negative* carbon of the arc, they do not work; but if the bell or the lamp is joined between the *positive* carbon of the arc and the third carbon, they are set in action by a strong current passing through them. These effects are produced, although the third carbon (which is best held at right angles to the other two forming the arc) is half or three quarters of an inch away from the positive and negative carbon, the sole condition being that the flame of the arc must touch or be projected by a magnet so as to touch this third carbon. We have, therefore, similar phenomena in the case of the arc and incandescence lamps.

(20.) When the electric arc is being projected against the third carbon, and has brought it down to the same potential, a galvanometer joined in between the two carbons shows no current; but this space between the negative carbon of the arc and the third carbon possesses a unilateral conductivity, and will pass the current from a small battery of secondary cells one way, but not the other. The secondary battery when joined in series with the galvanometer sends a current, if its negative pole is in connexion with the negative carbon of the arc, and its positive pole, through the galvanometer, with the third carbon; but if the secondary battery is reversed in position it sends no current. Negative electricity can pass along the flame-like projection of the arc from the hot negative carbon to the cooler third carbon, but not in an opposite direction.

(21.) If the arc is projected by means of a magnet for a long time against the third insulated carbon, it *craters* it out in the same fashion as the crater of the positive carbon, and the tip of this third carbon, where it has received the flame-like blast of the arc, is converted into graphite.

The same effects are observed if an iron rod is used as a third pole, and in this case the end is converted into *steel*, and rendered so hard as to be scarcely touched by the file when it has been quenched in water.

In seeking for an hypothesis to connect together these observed facts, the one which suggests itself as most in accordance with the facts is as follows:—

In the case of a carbon incandescence lamp when at vivid incandescence, carbon particles are being projected from all parts of the filament, but chiefly from the negative half of the loop. These carbon

molecules carry *negative* charges of electricity, and when they impinge upon a metal plate placed in the vacuum they can discharge themselves if this plate is positively electrified, either by being in metallic connexion with the positive electrode of the lamp or with a separate positively charged body. When the plate is simply insulated the stream of negatively charged carbon molecules brings down this insulated plate to the potential of the base of the negative leg, or to the potential of that part of the carbon conductor from which it is receiving projected molecules. These carbon molecules projected from an incandescent conductor can carry negative charges, but either cannot be positively charged, or else lose a positive charge almost instantly when projected off from the conductor.

In the case of the electric arc we must suppose that the negative carbon is projecting off a torrent of negatively electrified carbon molecules, and these, impinging against the positive carbon, wear out a crater in it by a sand-blast-like action.

The higher temperature of the positive carbon in a continuous current arc is thus explained as due to the impact of the carbon molecules projected from the negative carbon.

If the electric arc is diverted against a third insulated lateral carbon, the carbon blast from the negative carbon wears out a crater in it and brings it down to the same potential as itself. The actions going on in an electric arc may be considered to be somewhat as follows:—When the carbons are first put together, the resistance at the point of contact renders the extremities incandescent. When thus incandescent and separated, the electrification of each carbon is sufficient to begin the projection of molecules from both positive and negative carbons, probably most largely from the latter. The impact of the molecular stream from the negative pole raises the temperature of the positive carbon, and this again by radiation raises the temperature of the negative carbon end. The electromotive force is thus able to keep up a projection of negatively charged carbon molecules from the end of the negative carbon, which molecules are loosened from the mass by heat, and then move away by electric repulsion from the surface in virtue of the electric charge which they retain. It would seem as if a hot carbon molecule cannot retain a positive charge, and hence the potential difference between a third insulated carbon and the positive carbon of the arc is nearly the same as the potential difference of the positive and negative carbons of the arc. The rise of potential along the arc takes place very suddenly just in the neighbourhood of the crater of the positive carbon.

It has often been suggested that the electric arc contains a counter-electromotive force. It is questionable whether such experiments as those of Edlund ('*Phil. Mag.*,' vol. 36, 1868, p. 352) are entirely conclusive on this point.



It has been shown by other experimenters\* that for arcs of varying length, but the same current, beyond a certain small initial length, the potential difference necessary to maintain the arc is proportional to the length of the arc plus a constant. This might thus be interpreted to mean that a certain proportion of the working electromotive force of the arc was employed in detaching the carbon molecules from the mass of the poles, and that the excess alone is represented by the current produced in an arc of definite length.

In the case of the incandescence lamps the hypothesis of the projection of negatively charged carbon molecules from the incandescent conductor, to which the name of *molecular electrovection* may be given, will suffice to explain all the various different effects produced by varying the surface, position, and distance of the metal plate against which they impinge, and also the nullifying effect of shielding this plate from the negative leg of the carbon.

That this molecular discharge goes on chiefly from the negative leg is additionally proved by the greater erosion which takes place in the deposit of carbon on the negative leg when the carbon is uniform and traversed by a continuous current.

The hypothesis that a carbon molecule detached from an incandescent carbon surface in a high vacuum can only convey away a negative charge, reconciles also the above described observed effects in which a negative discharge can be made out of a hot surface of carbon more easily than a positive discharge. When an electromotive force is applied to two metallic terminals or electrodes sealed into a good vacuum, it is well known that a certain initial electromotive force has to be applied before any electric current begins to flow through the gas at all. It seems conclusively proved by Mr. Crookes's researches that the nature of an electric discharge through a high vacuum consists in a torrent of electrified particles proceeding from the negative electrode. If this is the case the initial electromotive force required to begin a discharge through such rarefied gas would naturally be reduced by heating the negative electrode, so as to favour and assist the detachment of the charged molecules of that electrode. The effect of heating the negative electrode in facilitating discharge through vacuum spaces has previously been described by W. Hittorf ('*Annalen der Physik und Chemie*,' vol. 21, 1884, p. 90—139), and it is abundantly confirmed by the above experiments. We may say that a vacuum space bounded by two electrodes—one incandescent, and the other cold—possesses a unilateral conductivity for electric discharge when these electrodes are within a distance of the mean free path of projection of the mole-

\* See Professors Ayrton and Perry, '*Proceedings of the Physical Society*,' vol. 5, p. 201.

cules which the impressed electromotive force can detach and send off from the hot negative electrode.

This unilateral conductivity of vacuum spaces having unequally heated electrodes has been examined by MM. Elster and Geitel (see 'Wiedemann's Annalen,' vol. 38, 1886, p. 40), and also by Goldstein ('Wied. Ann.,' vol. 24, 1885, p. 83), who in experiments of various kinds have demonstrated that when an electric discharge across a vacuum space takes place from a carbon conductor to another electrode, the discharge takes place at lower electromotive force when the carbon conductor is the negative electrode and is rendered incandescent.

III. "A Milk Dentition in *Orycteropus*." By OLDFIELD THOMAS, Natural History Museum. Communicated by Dr. A. GÜNTHER, F.R.S. Received December 12, 1889.

[Publication deferred.]

*Presents, January 9, 1890.*

Transactions.

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[fol. 2995] DEFENDANT'S EXHIBIT J 1

*Proceedings of Royal Institution of Great Britain, 1890-1892*

Weekly Evening Meeting, Friday, February 14, 1890. William Crookes, Esq., F.R.S. Vice-President, in the Chair. Professor J. A. Fleming, M.A., D.Sc., M.R.I. Problems in the Physics of an Electric Lamp

More than eighty years ago Sir Humphry Davy provided the terminal wires of his great battery of 2000 pairs of plates with rods of carbon, and, bringing their extremities in contact, obtained for the first time, a brilliant display of the electric arc.<sup>1</sup> The years that have fled away since that time have seen all the marvelous developments of electro-magnetic engineering, have placed in our possession the electric glow-lamp, and brought the art of electrical illumination to a condition in which it progresses each year with giant strides. In addition to the importance attaching to their ever-increasing industrial use, there are many questions of purely scientific interest which present themselves to our minds when we proceed to examine the actions [fol. 2996] that take place when a carbon conductor is rendered incandescent in a high vacuum, or when an electric arc is formed between two carbon poles. It is to a very few of these physical problems that I desire to direct your attention to-night, but more especially to one which is particularly interesting from the bearing which it has on the general nature of electric discharge.

We know as a very familiar fact that if we attempt to raise the temperature of a carbon conductor enclosed in a vacuum beyond a certain limit, not far removed from the melting point of platinum, the carbon begins to volatilise

<sup>1</sup> Sir Humphry Davy laid a request before the managers of the Royal Institution on July 11th, 1808, that they would set on foot a subscription for the purchase of a large galvanic battery. The result of this suggestion was that a galvanic battery of 2,000 pairs of copper and zinc plates were set up in the Royal Institution, and one of the earliest experiments performed with it was the production of the electric arc between carbon poles, on a large scale. It is probable, however, that Davy had produced the light on a small scale some six years before and, according to Quetelet, Curtet observed the arc between carbon points in 1802. See Dr. Paris' "Life of Sir H. Davy."

with great rapidity. If an electric glow-lamp has passed through its carbon more than a certain strength of current, the glass bulb speedily becomes darkened by a deposit of this volatilised carbon condensed upon it; and experience shows us that we cannot raise the temperature of that carbon beyond a definite point without causing this waste of the conductor to become very rapid. In the highly rarefied atmosphere within the bulb of a glow lamp, the carbon, when at its normal incandescence, must be considered to be projecting off molecules of carbon in all directions, partly in virtue of purely thermal actions, but probably also in consequence of certain electrical effects to be presently discussed. This scattering of the material of the carbon conductor takes place with disadvantageous rapidity from an industrial point of view at and beyond a certain temperature,<sup>2</sup> but it exists as well at much lower temperatures than that which is found to determine the practical limit of durability. A curious appearance is found in many incandescent lamps which have been "over-run," which shows us that this projection of carbon molecules from the hot conductor is not, perhaps, best described by calling it a vaporisation of its substance, but that the surface molecules are shot off in straight lines, and that they reach the glass envelope without being hindered to any great extent by the molecules of the residual air.

If an electric current is passed through an otherwise uniform carbon conductor, which possesses at any one place a specific resistance higher than that of the remaining portion, the current, in accordance with a well-known law, there develops a higher temperature, and the molecular scattering at that spot may in consequence be greatly exaggerated. It may be that the detrition of the conductor at that locality will be so great as to cut it through after a very short time. When the carbon has the form of a simple horseshoe loop, and when this molecular scattering takes place from some point in the middle of one branch, the molecular projection makes itself evident by producing a

<sup>2</sup> When the rate of expenditure of energy in the carbon conductor is raised until it reaches a value of about 500 watts, or 360 foot pounds per second per square inch of radiative surface, a limit of useful temperature has been reached for economical working, under the usual present conditions of steam-engine-driven dynamos and modern glow-lamps.

"molecular shadow" of the other leg upon the interior of the glass. I will project upon the screen an image of the carbon horseshoe loop taken from an old glow-lamp, and you will be able to see that the filament has been cut through at one place. At that position some minute congenital defect caused the carbon to have a higher resistance, the temperature at that point when it was in use became excessive, and an intensified molecular scattering took place from that locality. On examining the glass bulb from which it was taken, we find that the glass has been everywhere darkened by a deposit of the scattered carbon except along one narrow line (*see* Fig. 1), and that line is in the plane of the carbon loop and on the side opposite to the point of rupture of the filament.<sup>3</sup>

I may illustrate to you by a very simple experiment the way in which that "shadow" has been formed. Here is a  $\cap$ -shaped rod: this shall represent the carbon conductor in the lamp; this sheet of cardboard placed behind it, the side of the glass receiver. I have affixed a little spray-producer to one side of the loop, and from that point blow out a spray of inky water. Consider the ink spray to represent the carbon atoms shot off from the overheated spot. We see that the cardboard is bespattered on all points except along one line where it is sheltered by the opposite side of the loop. We have thus produced a "spray shadow" on the board (Fig. 2). The existence of these molecular shadows in incandescent lamps leads us therefore to recognise that the carbon atoms must be shot off in straight lines, or else obviously no such sharp shadow could thus be formed. This phenomenon confirms in a very beautiful manner the deductions of the Kinetic theory of gases. I may remind you that at the ordinary temperature and pressure the mean free path of a molecule of air is deducted to be about four one-millionths of an inch. This is the average distance which such a gaseous molecule moves over before meeting with a collision against a neighbour which changes [fol. 2998] the direction of its path. Let the air be rarefied, as in these bulbs, to something like a millionth of the ordinary atmospheric pressure, and the mean free path is increased to several inches. The space within the bulb though from one point of view densely populated with

<sup>3</sup> The writer desires to express his indebtedness to the Editor of the "Electrician" for the loan of the blocks illustrating this abstract.

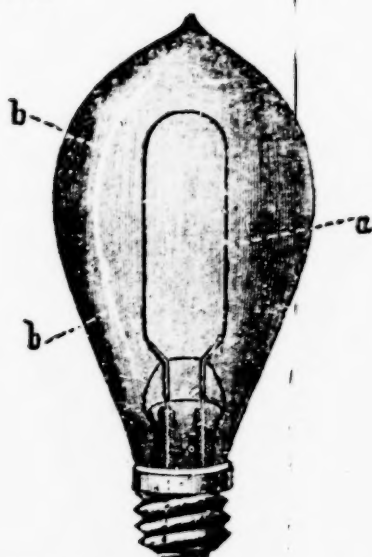


FIG. 1. Glow-lamp, having the glass bulb blackened by deposit of carbon, showing the molecular scattering which has taken place from the point *a* on the filament, and the shadow in line of no deposit produced at *b*.

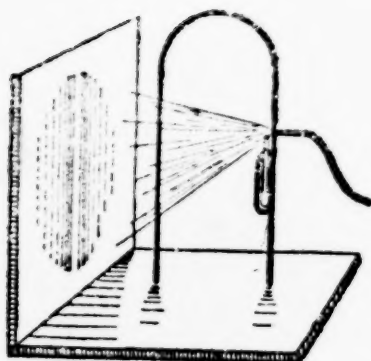


FIG. 2. "Spray shadow" of a rod thrown on cardboard screen to illustrate formation of molecular shadow in glow lamps.

molecules of residual air—is yet, as a fact, in such a condition of rarefaction that a carbon molecule projected from the conductor can move over a distance of three or four inches on an average without meeting with interference by collision with another molecule, and the facts revealed to us by these shadows show that this must be the case. I have also at hand some Edison lamps in which these "molecular shadows" are finely shown, but in these cases the deposit on the interior of the bulb is not carbon but copper, because the molecular scattering has here taken place by excessive temperature developed at the copper clamps by which the

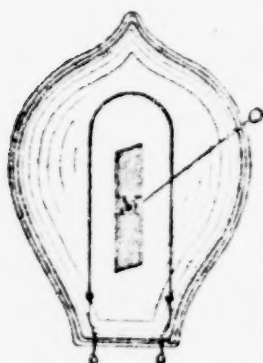
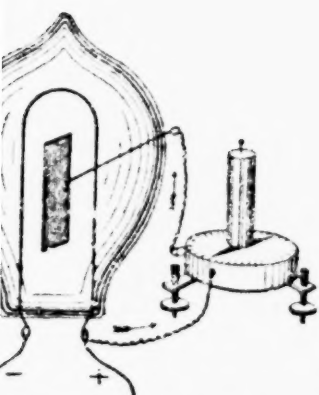


FIG. 3. Glow-lamp, having insulated metal middle plate *M* sealed into bulb to exhibit "Edison effect."

carbon filament is attached to the platinum wires. The theory, however, is the same. The deposit of copper shows a fine green colour by transmitted light in the thinner portions. One curious lamp also before me had by an accident an aluminium plate volatilised within the bulb. The glass receiver has in consequence been covered with a mirror-like deposit of aluminium, which on the thinner portions shows a fine blue colour by transmitted light, and a silvery lustre by reflected light. This lamp also shows a fine "molecular shadow."

These facts prepare us to accept the view that when a glow-lamp is in operation the highly rarefied residual air in the interior of the bulb is being traversed in all directions by multitudinous carbon atoms projected off from the incandescent carbon conductor. I now wish to pass in review before you some facts which indicate that these carbon atoms carry with them electric charges, and that they are charged, if at all, with *negative electricity*. I may preface all by saying that much of what I have to show you will be seen to be closely related to the phenomena studied by Mr. Crookes in his splendid and classical researches on radiant matter. Our starting-point for this purpose is a discovery made by Mr. Edison in 1884, and which received careful examination at the hands of Mr. Preece in the following year,<sup>1</sup> and by myself more recently. Here is the initial experiment. A glow-lamp having the usual horse-shaped carbon (*see* Fig. 3) has a metal plate held on a platinum shoe wire sealed through the glass bulb. This plate is so fixed out it stands up between the two sides of the carbon arch without touching either of them. We shall illuminate the lamp by continuous current of electricity, and for brevity's sake speak of that half of the loop of carbon on the side by which the current enters it as the positive leg, [fol. 2999] and the other half of the loop as the negative leg. The diagram in Fig. 4 shows the position of the plate with respect to the carbon loop. There is a distance of half an inch, or in some cases many inches, between either leg of the carbon and this middle plate. Setting the lamp in action, I connect a sensitive galvanometer between the middle plate and the *negative terminal* of the lamp, and you see that there is no current passing through the instrument. If, however, I connect the terminals of my galvanometer to the middle plate and to the *positive electrode* of the lamp, we find a current of some milliamperes is passing through it. The diagrams in Fig. 5 show the mode of connection of the galvanometer in the two cases. This effect, which is often spoken of as the "Edison effect," clearly indicates that an insulated plate so placed in the vacuum of a lamp in action is brought down to the same potential or electrical

<sup>1</sup> Mr. Preece's interesting paper on this subject is published in the "Proceedings" of the Royal Society for 1885, p. 219. See also "The Electrician," April 4th, 1885, p. 436.



Sensitive galvanometer connected between the middle plate and positive electrode of a glow-lamp, showing current flowing through it when the lamp is in action ("Edison effect").

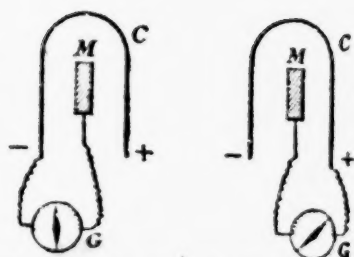


Fig. 5.—Mode of connection of galvanometer *G* to middle plate *M* and carbon horseshoe shaped conductor *C* in the experiment of the "Edison effect."

as the negative electrode of the carbon loop. On turning the direction of the current through the galvanometer we find that it is equivalent to a flow of negative electricity taking place through it *from* the middle plate *to* positive electrode of the lamp. A consideration of this shows us that there must be some way by which negative electricity gets across the vacuum space from the negative leg of the carbon to the metal plate, whilst at the same time a negative charge cannot pass from the metal plate to the positive leg. Before I pass away from this experiment, I should like to call your attention to a curious effect at the moment when the lamp is extinguished. Connecting the galvanometer as at first, between the middle plate and the negative electrode of the lamp, we notice that when made highly sensitive the galvanometer indicates a current flowing through it whilst the lamp is in action. Turning off the current from the lamp produces, as you know, a violent kick or deflection of the galvanometer, indicating a sudden rush of current through it.

In endeavoring to ascertain further facts about this effect the experiments which early suggested itself was one [?] directed to determine the relative effects of different portions of the carbon conductor. Here is a lamp (Fig. 6) in which one leg of the carbon horseshoe has been enclosed in a glass tube of the size of a quill, which is in one-half of the carbon. The bulb contains, as before, an insulated middle plate. If we pass the actuating current through this lamp in such a direction that the enclosed or sheathed leg is the *positive* leg, we find the

effect existing as before. A galvanometer connected between the plate and positive terminal of the lamp yields a strong current, whilst if connected between the negative terminal and the middle plate there is no current at all. Let us, however, reverse the current through the lamp so that the shielded or enclosed leg is now the negative one, and the galvanometer is able to detect no current, whether connected in one way or the other. We establish, therefore, the conclusion that it is the negative leg of the carbon loop which is the active agent in the production of this "Edison effect," and that if it is enclosed in a tube of either glass or metal, no current is found flowing in a galvanometer connected between the positive terminal of the lamp and this middle collecting plate.

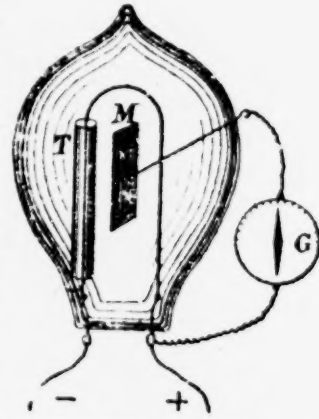


FIG. 6. Glow-lamp having negative leg of carbon enclosed in glass tube *T*, the "Edison effect" thereby being annulled or greatly diminished.

Another experiment which confirms this view is as follows:—This lamp (*see* Fig. 7) has a middle plate, which is provided with a little mica flap or shutter on one side of it. When the lamp is held upright the mica shield falls over and covers one side of the plate, but when it is held in a horizontal position the mica shield falls away from the front of the plate and exposes it. Using this lamp as before we find that when the positive leg of the carbon loop is opposite to the shielded face of the plate, we get the "Edison effect" as before in any position of the lamp. Reversing the lamp current and making that same leg the *negative* one, we find that when the lamp is so held the metal plate is shielded by the interposition of the mica, and the galvanometer current is very much less than when the shield is shaken on one side and the plate exposed fully to the negative leg.

At this stage it will perhaps be most convenient to outline briefly the beginnings of a theory proposed to reconcile these facts, and leave you to judge how far the subsequent experiments confirm this hypothesis. The theory very briefly is as follows: From all parts of the incandescent carbon loop, but chiefly from the negative leg, carbon molecules are being projected which carry with them, or are charged with, negative electricity. I will in a few moments make a suggestion to you which may point to a possible

hypothesis on the manner in which the molecules acquire this negative charge. Supposing this, however, to be the case, and that the bulb is filled with these negatively-charged molecules, what would be the result of introducing [fol. 300d] into their midst a conductor such as this middle metal plate which is charged positively? Obviously, they would all be attracted to it and discharge against it. Suppose the positive charge of this conductor to be continually renewed, and the negatively-charged molecules continually supplied, which conditions can be obtained by connecting the middle plate to the positive electrode of the lamp, the obvious result will be to produce a current of electricity flowing through the wire or galvanometer, by means of which this middle plate is connected to the positive electrode of the lamp. If, however, the middle plate is connected to the negative electrode of the lamp,

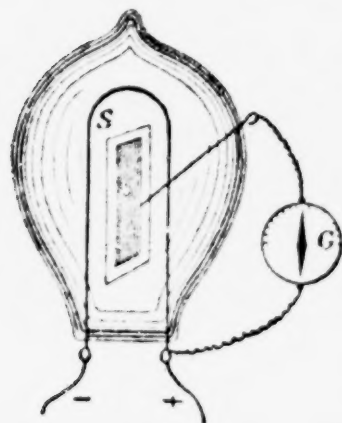


FIG. 7. — Glow-lamp having iron shield *S* interposable between middle plate *M* and negative leg of carbon, thereby diminishing the "Edison effect."

the negatively-charged molecules can give up no charge to it, and produce no current in the interpolated galvanometer. We see that on this assumption the effect must necessarily be diminished by any arrangement which prevents these negatively-charged molecules from being shot off the negative leg or from striking against the middle plate. Another obvious corollary from this theory is that the "Edison effect" should be annihilated if the metal collecting plate is placed at a distance from the negative leg much greater than the mean free path of the molecules.

Here are some experiments which confirm this deduction. In this bulb (Fig. 8) the metal collecting plate, which is to be con-

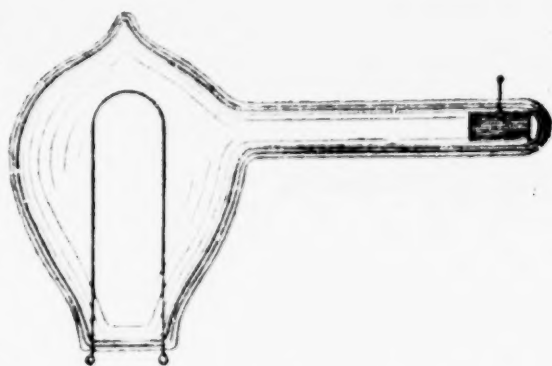


FIG. 8. — Collecting plate placed at end of a tube, its length, opening out of the bulb.

connected through the galvanometer with the positive terminal of the lamp, is placed at the end of a long tube opening out of and forming part of the bulb. We find the "Edison effect" is entirely absent, and that the galvanometer current is zero. We have, as it were, placed our target at such a distance that the longest range molecular bullets cannot hit it, or, at least, but very very few of them do so. Here again is a lamp in which the plate is placed at the extremity of a tube opening out of the bulb, but bent at right angles (Fig. 9). We find in this case, as first discovered by Mr. Preece, that there is no "Edison effect." Our molecular marksman cannot shoot round a corner. None of the negatively-charged molecules can reach the plate, although that plate is placed at a distance not greater than [fol. 3002] would suffice to produce the effect if the bend were straightened out. Following out our hypothesis into its consequences would lead us to conclude that the material of which the plate is made is without influence on the result, and this is found to be the case. Many of the foregoing facts were established by Mr. Preece as far back as 1885, and I have myself abundantly confirmed his results.

We should expect also to find that the larger we make our plate, and the nearer we bring it to the negative leg of the carbon, the greater will be the current produced in a circuit connecting this plate to the positive terminal of the lamp. I have before me a lamp with a large plate placed very near the negative leg of the carbon of a lamp, and we find that we can collect enough current from these molecular charges to work a telegraph relay and ring an electric bell. The current which is now working this relay is made up of the charges collected by the plate from the negatively-charged carbon molecules which are projected against it from the negative leg, across the highly perfect vacuum. I have tried experiments with lamps in which the collecting plate is placed in all kinds of positions, and has various forms, some of which are here, and are represented in the diagrams before you; but the result may all be summed up by saying that the greatest effects are pro-

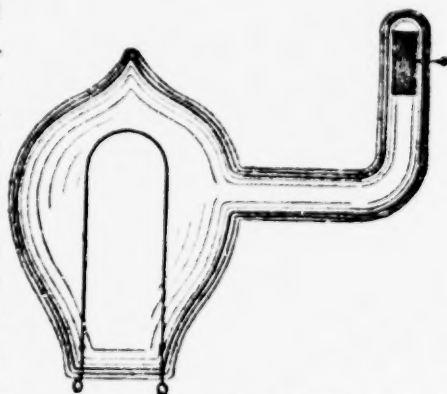


FIG. 9. Collecting plate placed at end of an elbow tube opening out of the bulb.

duced when the collecting plate is as near as possible to the base of the negative end of the loops, and, as far as possible, encloses, without touching, the carbon conductor. Time will not permit me to make more than a passing reference to the fact that the magnitude of the current flowing through the galvanometer when connected between the middle plate and the positive terminal of the lamp often "jumps" from a low to a high value, or *vice versa*, in a remarkable manner, and that this sudden change in the current can be produced by bringing strong magnets near the outside of the bulb.

Let us now follow out into some other consequences this hypothesis that the interior of the bulb of a glow-lamp when in action is populated by flying crowds of carbon atoms all carrying a negative charge of electricity. Suppose we connect our middle collecting plate with some external reservoir of electric energy, such as a Leyden jar, or with a condenser equivalent in capacity to many hundreds of Leyden jars, and let the side of the condenser which is charged positively be first placed in connection through a galvanometer with the middle plate (see Fig. 10), whilst the negative side is placed in connection with the earth. Here is a condenser of two microfarads capacity so charged and connected. Note what happens when I complete the circuit and illuminate the lamp by passing the [fol. 2003] current through its filament. The condenser is at once discharged. If, however, we repeat the same experiment with the sole difference that the negatively charged side of the condenser is in connection with the middle plate then there is no discharge. The experimental results may be regarded from another point of view. In order that the condenser may be discharged as in the first case, it is essential that the negatively charged side of the condenser shall be in connection with some part of the circuit of the incandescent carbon loop. This experiment with the condenser discharged by the lamp may be then looked upon as an arrangement in which the plates of a charged condenser are connected respectively to an incandescent carbon loop and to a cool metal plate, both being enclosed in a highly vacuum space, and it appears that when the incandescent conductor is the negative electrode of this arrangement the discharge takes place, but not when the cooler metal plate is the negative electrode of the charged

condenser. The negative charge of the condenser can be carried across the vacuous space from the hot carbon to the colder metal plate, but not in the reverse direction.

This experimental result led me to examine the condition of the vacuous space between the middle metal plate and the negative leg of the carbon loop in the case of the lamp employed in our first experiment. Let us return for a moment to that lamp. I join galvanometer between the middle plate and the negative terminal of the lamp, and find, as before, no indication of a current. The metal plate and the negative terminal of the lamp are at the same electrical potential. In the circuit of the galvanometer we will insert a single galvanic cell having an electromotive force of rather over one volt. In the first place let that cell be so inserted that its negative pole is in connection with the middle plate, and its positive pole in connection through the galvanometer with the negative terminal of the lamp (see Fig. 11). Regarding the circuit of that cell alone, we find that it consists of the cell itself, the galvanometer wire, and that half-inch of highly vacuous space between the hot carbon conductor and the middle plate. In that circuit the cell cannot send any sensible current at all, as it is at the present moment connected up. But if we reverse the direction of the cell so that its positive pole is in connection with the middle plate, the galvanometer at once gives indications of a very sensible current. This highly vacuous space, lying between the middle metal plate on the one hand, and the incandescent carbon on the other, possesses a kind of unilateral conductivity, in that it will allow the current from [fol. 3004] a single galvanic cell to pass one way but not the other. It is a very old and familiar fact that in order to send a current from a battery through a highly rarefied gas by means of metal electrodes, the electromotive force of the battery must exceed a certain value. Here, however, we have indication that if the negative electrode by which that current seeks to enter the vacuous space is made incan-

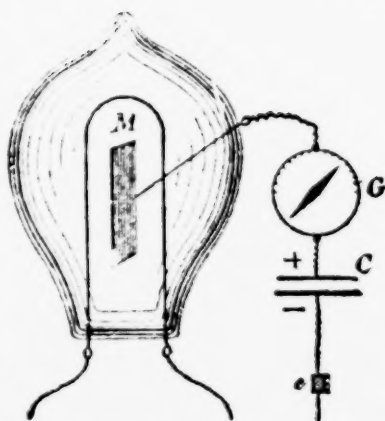


FIG. 10. Charged condenser *C* discharged by middle plate *M*, when the positively charged side of condenser is in connection with the plate and other side to earth *e*.

descent the current will pass at a very much lower electromotive force than if the electrode is not so heated.

A little consideration of the foregoing experiments led to the conclusion that in the original experiment, as devised by Mr. Edison, if we could by any means render the middle plate very hot, we should get a current flowing through a galvanometer when it is connected between the middle plate and the negative electrode of the carbon. This experiment can be tried in the manner now to be shown. Here is a bulb (Fig. 12) having in it two carbon loops; one

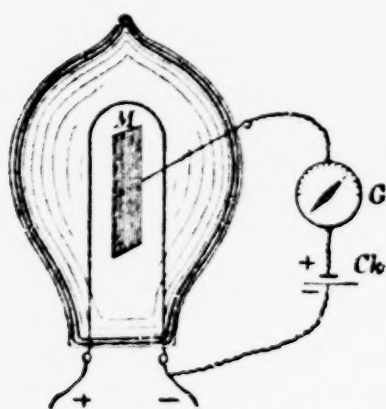


FIG. 11. Current from Clark cell *Cl* being sent across vacuum space between negative leg of carbon and middle plate *M*. Positive pole of cell in connection with plate *M* through galvanometer *G*.

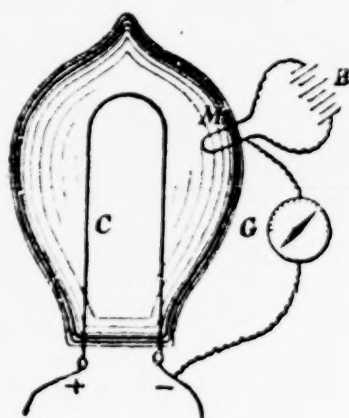


FIG. 12. Experiment showing that when the "middle plate" is a carbon loop rendered incandescent by insulated battery *B*, a current of negative electricity flows from *M* to the positive leg of main carbon *C* across the vacuum.

of these is of ordinary size, and will be rendered incandescent by the current from the mains. The other loop is very small, and will be heated by a well-insulated secondary battery. This smaller incandescent loop shall be employed just as if it were a middle metal plate. It is, in fact, simply an incandescent middle conductor. On repeating the typical experiment with this arrangement, we find that the galvanometer indicates a current when connected between the middle loop and either the positive *or* the negative terminal of the main carbon. I have little doubt but that if we could render the platinum plate in our first used lamp incandescent by concentrating on it from outside a powerful beam of radiant heat we should get the same result.

A similar set of results can be arrived at by experiments

with a bulb constructed like an ordinary vacuum tube, and having small carbon loops at each end instead of the usual platinum or aluminium wires. Such a tube is now before you (*see* Fig. 13), and will not allow the current from a few cells of a secondary battery to pass through it when the carbon loops are cold. If, however, by means of well insulated secondary batteries we render both of the carbon loop electrodes highly incandescent, a single cell of a battery is sufficient to pass a very considerable current across that vacuous space provided the resistance of the rest of the circuit is not large. We may embrace the foregoing facts by saying that if the electrodes, but especially the negative electrode, which form the means of ingress and egress of a current into a vacuous space are capable of being rendered highly incandescent, and if at that high temperature they are made to differ in electrical potential by the application of a very small electromotive force, we may get under these circumstances a very sensible current through the rarefied gas. If the electrodes are cold a very much higher electromotive force will be necessary to begin the discharge or current through the space. These facts have been made the subject of elaborate investigation by Hittorf and Goldstein, and more recently by Elster and Geitel. It is to Hittorf that I believe we are indebted for the discovery of the fact that by heating the negative elec-

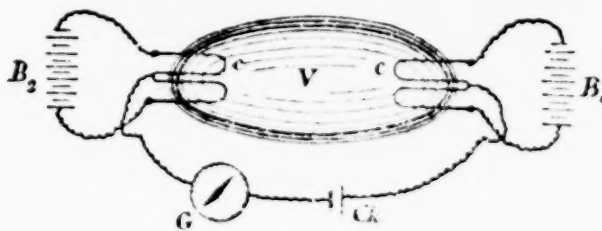


FIG. 13. Vacuum tube having carbon loop electrodes, *cc*, at each end rendered incandescent by insulated batteries *B, B*, showing current from Clark coil, *Ck*, passing through the high vacuum when the electrodes are incandescent.

trode we greatly reduce the apparent resistance of a vacuum.

Permit me now to pave the way by some other experiments for a little more detailed outline of the manner in which I shall venture to suggest these negative molecular

charges are bestowed. This is really the important matter to examine. In seeking for some probable explanation of the manner in which these wandering molecules of carbon in the glow-lamp bulb obtain their negative charges, I fall back for assistance upon some facts discovered by the late Prof. Guthrie. He showed some years ago new experiments on the relative powers of incandescent bodies for retaining positive and negative charges. One of the facts he brought forward<sup>2</sup> was that a bright red-hot iron ball, well insulated, could be charged negatively, but could not retain for an instant a positive charge. He showed this fact in a way which it is very easy to repeat as a lecture experiment. Here is a gold-leaf electroscope, to which we will impart a positive charge of electricity, and project the image of its divergent leaves on the screen. A poker, the tip of which has been made brightly red-hot, is placed so that its incandescent end is about an inch from the knob of the electroscope. No discharge takes place. Discharging the electroscope [fol. 3006] with my finger, I give it a small charge of negative electricity, and replace the poker in the same position. The gold leaves instantly collapse. Bear in mind that the extremity of the poker, when brought in contiguity to the knob of the charged electroscope, becomes charged by induction with a charge of the opposite sign to that of the charge of the electroscope, and you will at once see that this experiment confirms Prof. Guthrie's statement, for the negatively-charged electroscope induces a positive charge on the incandescent iron, and this charge cannot be retained. If the induced charge on the poker is a negative charge, it is retained, and hence the positively-charged electroscope is not discharged, but the negatively-charged electroscope at once loses its charge. Pass in imagination from iron balls to carbon molecules. We may ask whether it is a legitimate assumption to suppose the same fact to hold good for them, and that a hot carbon molecule or small carbon mass just detached from an incandescent surface behaves in the same way and has a greater grip for nega-

<sup>2</sup>"On a New Relation between Electricity and Heat," *Phil. Mag.* vol. xlv. p. 308. 1873.

tive than for positive charge? If this can possibly be assumed, we can complete our hypothesis as follows:—Consider a carbon molecule or small congerie of molecules just set free by the high temperature from the negative leg of the incandescent carbon horseshoe. This small carbon mass finds itself in the electrostatic field between the branches of the incandescent carbon conductor (*see* Fig. 14). It is acted upon inductively, and if it behaves like the hot iron ball in Prof. Guthrie's experiment it loses its positive charge. The molecule then being charged negatively is repelled along the lines of electric force against the positive leg. The forces moving it are electric forces, and the repetition of this action would cause a torrent of negatively-charged molecules to pour across from the negative to the positive side of the carbon horseshoe. If we place a metal plate in their path, which is in conducting connection with the positive electrode of the lamp carbon, the negatively-charged molecules will discharge themselves against it. A plate so placed may catch more or less of this stream of charged molecules which pour across between the heels of the carbon loop. There are many extraordinary facts, which as yet I have been able only imperfectly to explore, which relate to the sudden changes in the direction of the principal stream of these charged molecules, and to their guidance under the influence of magnetic forces. The above rough sketch of a theory must be taken for no more than it is worth, viz. as a working hypothesis to suggest further experiments.

These experiments with incandescence lamps have prepared the way for me to exhibit to you some curious facts with respect to the electric arc, and which are analogous to those which we have passed in review. If a good electric arc is formed in the usual way, and if a third insulated carbon held at right angles to the other two is [fol. 3007] placed so that its tip just dips into the arc (*see* Fig. 15), we can show a similar series of experiments. It is rather more under control if we cause the arc to be

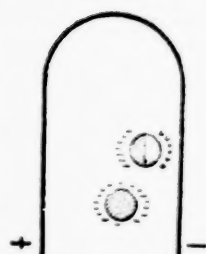
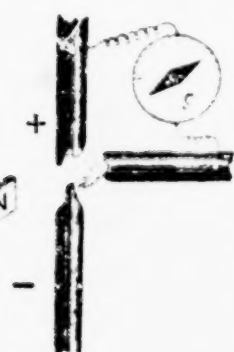


FIG. 14. Rough diagram illustrating a theory of the manner in which projected carbon molecules may acquire a negative charge.

ed against the third carbon by means of a magnet, now formed on the screen an image of the carbon and the arc between them, in the usual way. Placing a magnet at the back of the arc, I cause the flame of the arc to be deflected laterally and to blow against a third carbon held in it. There are three insulated wires connected respectively to the positive and to the negative carbon of the arc, and to the third or insulated carbon, one of which dips into the flame of the arc projected by the magnet. On starting the arc this third carbon is immediately brought down to the same electrical potential as the positive carbon of the arc, and if I connect this galvanometer in between the negative carbon and the third insulated carbon I get, as you see, no indication of a current.

Let me, however, change the connections and connect the circuit of my galvanometer in between the positive carbon of the arc and the middle carbon, and we find

evidence, by the violent impulse given to the galvanometer, that there is a strong current flowing through it. The direction of this current is equivalent to a flow of negative electricity from the middle carbon through the galvanometer to the positive carbon of the arc. We have here then the "Edison effect" repeated with the electric arc. So strong is the current flowing in a circuit connecting the middle carbon with the positive carbon that I can, as you see, ring an electric bell and light a small incandescent lamp



Electric arc projected by magnet against a third carbon, and a strong electric current flows through a galvanometer connected between the positive and middle carbon.

These electric-current detectors are placed in connection with the positive and middle carbons.

So find that the flame-like projection of the arc between the negative carbon possesses a unilateral conductivity. Connect this small secondary battery of fifteen cells in series with the galvanometer, and connect the two between the positive carbon and the negative carbon of the arc. Just as in the analogous experiment with the incandescent lamp, we can send negative electricity along the flame of the arc one way but not the other. The secondary battery

causes the galvanometer to indicate a current flowing through it when its negative pole is in connection with the negative carbon of the arc (see Fig 16), but not when its positive pole is in connection with the negative carbon. On examining the third or middle carbon after it has been employed in this way for some time, we find that its extremity is cratered out and converted into graphite, just as if it had been employed as the positive carbon in forming an electric arc. Time forbids me to indulge in any but the briefest remarks on these experiments; but one suggestion may be made, and that is that they seem to indicate that the chief movement of carbon molecules in the electric arc is *from* the [fol. 3008] negative *to* the positive carbon. The idea suggests itself that, after all, the cratering out of the positive carbon of the arc may be due to a sand-blast-like action of this torrent of negatively-charged molecules which are projected from the negative carbon. If we employ a soft iron rod as our lateral pole, we find that, after enduring for some time the projection of the arc against it, it is converted at the extremity into *steel*.

Into the fuller discussion as to the molecular actions going on in the arc, the source and nature of that which has been called the counter-electromotive force of the arc, and the causes contributing to produce unsteadiness and hissing in the arc, I fear that I shall not be able to enter, but will content myself with the exhibition of one last experiment, which will show you that a high vacuum, or, indeed, any vacuum, is not necessary for the production of the "Edison effect." Here is a

carbon horseshoe-shaped conductor, not enclosed in any receiver (see Fig. 17). Close to the negative leg or branch, yet not touching it, we have adjusted a little metal plate. The sensitive galvanometer is connected between this metal plate and the base of the other or positive leg of this carbon arch. On sending a current through the carbon sufficient to

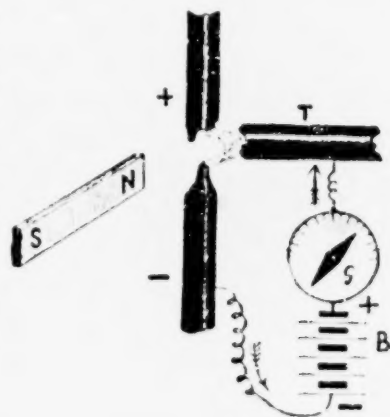


FIG. 16. Galvanometer *G* and battery *B* inserted in series between negative carbon of electric arc and a third carbon to show unilateral conductivity of the arc between the negative and third carbons.

bring it to bright incandescence, the galvanometer gives indications of a current flowing through it, and as long as the carbon endures, which is not, however, for many seconds,

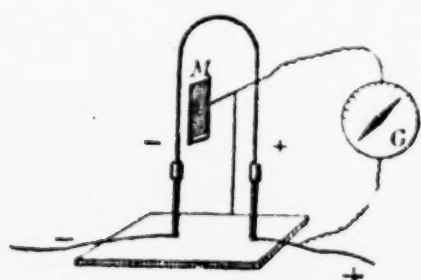


FIG. 17.—Edison effect<sup>6</sup> experiment shown with carbon in open air.

there is a current of electricity through it equivalent to a flow of negative electricity from the plate through the galvanometer to the positive electrode of the carbon. The interposition of a thin sheet of mica between the metal plate and the negative leg of the carbon loop entirely destroys the galvanometer current.<sup>6</sup>

These experiments and brief expositions cover a very small portion of the ground which is properly included within the limits of my subject. Such fragments of it as we have been able to explore tonight will have made it clear that it is a region abounding in interesting facts and problems in molecular physics. The glow-lamp and the electric arc have revolutionized our methods of artificial lighting, but they present themselves also as subjects of scientific study, by no means yet exhausted of all that they have to teach.

<sup>6</sup> This last experiment is due to my assistant, Mr. A. H. Bate.

[J. A. F.]

A WEEKLY ILLUSTRATED JOURNAL OF

# ELECTRICAL ENGINEERING, INDUSTRY AND SCIENCE

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## NOTES.

Mr. SWINBURNE'S Paper on "The Theory of Armature Reaction in Dynamos and Motors," read before the Institution of Electrical Engineers on the 13th inst., will be discussed conjointly with Mr. FESSenden's communication on "Some Points in Dynamo and Motor Design," read last night.

The simplicity introduced into dynamometer design in considering the subject from the magnetic point of view first suggested by Hockins and River has received independent confirmation in Mr. Swenson's valuable Paper. The author discusses the difficulties and suggests the solution is still further brought out by the use of the term "equivalent potential" and suggests a method by which this may be considered in parts, just as in internal and external circuits of conductors can be determined separately when the electric potentials and resistances are known. The interesting point of magnetic leakage is also briefly covered. There is, however, no justification for the use of the term of "magnetic potential".

The removal of the structure easily will save a lot of trouble in carrying out the tests, one of which consists in the cutting of a link of chain, while the other is the removal of the chain. In this way the weak, long effort on the removal of the parts of the pole pieces and its structuring is made more safe and in a simple and useful manner. An advantage of this is that a greater amount of sparking is obtained at the lower trials of single-magnet training.

In connection with the subject of magnetic potential, we may remind our readers that a very simple and convenient instrument for its measurement was described before the Physical Society of London some time ago by Mr. A. P. Chrysler. This instrument consists of a long solenoid of many turns wound on an elastic core so as to be flexible. One end of the helix is kept fixed while the other is moved quickly between the two places whose difference of magnetic potential is required. The ends of the coil are connected with a ballistic galvanometer and the impulse imparted to the needle is a measure of the potential difference required. This instrument might be useful in measuring the quantities referred to by Mr. Swinburne, and it seems clear that some such instrument would be of use in dynamo tests and in dynamo design.

The twenty or thirty persons who comprised Mr. HEATON'S audience at the Society of Arts on Tuesday afternoon were evidently too deeply concerned with the propriety of ocean postage rates to pay much heed to his thunders against telegraph cable rates, or to criticize too freely the manner of his advocacy. People, however, who can be got to a five o'clock meeting of that kind are mostly enthusiasts and may perhaps be excused for patiently, though silently, listening to Mr. HEATON'S unkind insinuations against anyone's opponents. The Chairman was apparently the only person to realize the compromising position in which the result of the Paper was placing the Society. Addressing the meeting at the conclusion of the discussion, Sir FREDERICK remarked that it was not to be expected that all would agree with views put forward on that platform, but so long as they were expressed with moderation and fairness, the Society was always ready to give them a hearing.

We cannot help thinking from this and other indications that the Government's ideas of moderation and compromise have been somewhat slackened by various passages in Mr. Hay's address, and we shall be much disappointed if some of its points are abandoned before the Paper gets published in the *Weekly Tribune*. The Society cannot quarrel against its anti-slavery policy, if at least by its efforts and intemperance it can help to the *abolition* of slavery in this country.

At Bath the "solid" system is being used for high tension alternating-current and arc-lighting wires.

Besides the systems already described, the Callender Company, as is well known, also make conduits on the Callender-Webber system. This is a drawing in-and-out system, with a separate hole for each cable. Messrs. Callender state that their experience of cables drawn into pipes several together is that, although it may be possible to add single cables when required, yet that the cables will overlay each other and get interlaced

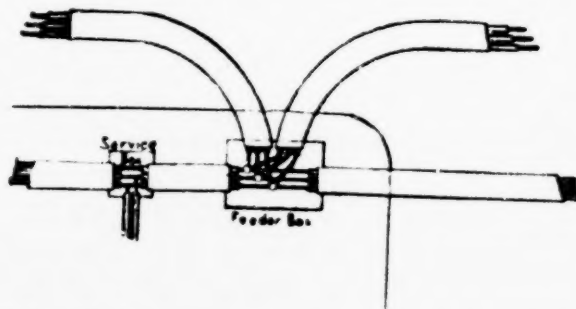


FIG. 20.—Callender Company's system. General method of running the mains and feeders (plan).

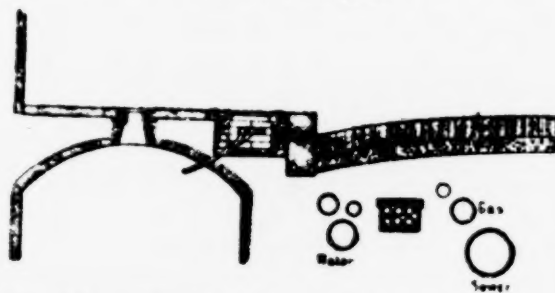


FIG. 21.—Callender Company's system. General method of running the mains and feeders (section).



FIG. 22.—Callender Webber system. Conduit general view.



FIG. 23.—Callender Webber system. Method of covering joints.

in such a way that it is very difficult to withdraw any one of them afterwards should it need repair. Figs. 20 and 21 show in plan and section the general method of running the feeders and mains. The feeders are usually carried under the road way and the service mains under the footpaths.

There are various ways in which the conduits are formed, according to the purpose for which they are to be used and the size of the cables they will have to carry. In the form which the Chelsea Electric Light Company are using the cables are laid

plain, without further protection, but in the work which has been put down for Messrs. A. and S. Gatti in the Strand, the bitumen conduit is enclosed in a three-sided iron trough, which is used upside down; that is, there is iron above but none below where the conduit rests on the ground. Figs. 22 and 23 show the general form of the conduits, the method of putting them, and of covering the joints. These bitumen conduits with the holes through them are made to project a couple of inches at each end beyond their iron case. To join them together, two are brought end to end, and a mandril of the proper size pushed through the holes into the next block so that they pass through the joints. The bitumen is then poured over the joint and the conduit pressed against its neighbour. A short piece of iron troughing of the same shape as the longer pieces containing the conduit is then made hot and slipped over the joint, melting the bitumen to some extent and making everything perfectly solid and water-tight. After the joint has had time to cool sufficiently, the mandrils are withdrawn, and the operation of the next section proceeded with. The Callender Company state that they are able to draw long lengths of cable into these conduits and to withdraw them if necessary.

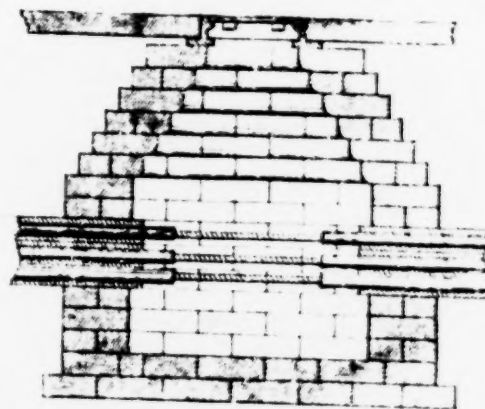


FIG. 24.—Callender Webber system. Manhole.

Junction boxes and manholes are used with this system, as per sketch (Fig. 24), being arranged to suit the requirements of each special case.

It will be noticed that in joining together the sections in the Callender-Webber system the blocks are simply made continuous, nothing being used at the joints. This is a somewhat important point, as the paper tubes used to keep the holes free at the joints, in work somewhat on the same lines in America, have proved a considerable source of subsequent trouble. It has often been objected to this class of conduit that it may crack, but in practice it is not found to do so; the bitumen, being of a slightly viscous nature, has always a certain amount of give in it.

#### CONCLUSION.

The description of the leading systems of laying underground mains at present in use is now concluded, and a tabulated list is appended giving the methods and systems employed in many of the best known installations, which in this form it is thought may prove useful, and to which the editor will be glad to receive any additions.

#### LIST OF CENTRAL ELECTRICAL LIGHT STATIONS SHOWING THE METHODS EMPLOYED AND THE TERTIARY SYSTEMS.

Town.	Company and System.	Underground Main.
London.	London Electric Supply Corporation, alternating, 2,500 volts.	India-rubber tubes, 12 inches diameter, 12 inches apart, 12 inches deep.
Metropolitan.	Electric Supply Company, alternating, 1,000 volts.	China-rubber tubes, 12 inches diameter, 12 inches apart, 12 inches deep.
House to House.	Electric Light Supply Company, alternating, 2,500 volts.	India-rubber tubes, 12 inches diameter, 12 inches apart, 12 inches deep.

Town.	Company and System.	Underground Mains.
London	Kensington and Knightsbridge Electric Lighting Company; low tension.	Cement conduits with bare copper rods on glass insulators. Callender cables when no room for this (Crompton system).
"	St. James and Pall Mall Electric Light Company; low tension.	Copper strips on china insulators in iron troughs.
"	Chelsea Electricity Supply Company; low tension and battery.	Callender-Welsher conduits and Callender cables.
"	Gatti Bros., Strand; low tension.	Callender-Welsher system.
"	Westminster Electric Supply Corporation; low tension.	Probably Crompton's system.
Bristol	Corporation; low tension.	Siemens' cables.
Leamington	Midland Electric Light and Power Company; low tension.	Brick conduits and Callender cables.
Bath	Bath Electric Light Works; arc and alternate, 2,000 volts.	Callender, solid conduits.
Eastbourne	Local Companies; alternating, 1,000 volts and arcs.	India rubber cables in iron pipes when underground.
Hastings		
Brighton		
Liverpool	Liverpool Electric Supply Company; low tension.	Callender, solid bitumen conduits.
Paris	Municipality, Halles Centrales; alternating, low tension.	Rubber covered cables on insulators in conduits and sewers.
Berlin	Low tension.	Siemens' armoured cables.
Rome		
Milan	Alternating, 2,000 volts.	Siemens' armoured concentric cables.
Turin		
New York	Edison Company; low tension.	Edison Company's system and cables, in separate iron pipes for feeders.
New York	Illuminating Company; chiefly arc.	Board of Electrical Control subways, chiefly iron pipes and hard rubber lead protected cables.
Chicago	Illuminating Company; chiefly arc.	Principally iron pipes with okonite cables in them, partly sewers.

## PROBLEMS IN THE PHYSICS OF AN ELECTRIC LAMP.\*

BY PROF. J. A. FLEMING, M.A., D.Sc., M.B.E.

More than eighty years ago Sir Humphrey Davy provided the terminal wires of his great battery of 2,000 pairs of plates with rods of carbon, and, bringing their extremities in contact, obtained for the first time a brilliant display of the electric arc. The years that have fled away since that time have seen all the marvellous developments of electro-magnetic engineering, have placed in our possession the electric glow lamp, and brought the art of electrical illumination to a condition in which it progresses each year with giant strides. In addition to the importance attaching to their ever increasing industrial use, there are many questions of purely scientific interest which present themselves to our minds when we proceed to examine the actions that take place when a carbon conductor is rendered incandescent in a high vacuum, or when an electric arc is formed between two carbon poles. It is to a very few of these physical problems that I desire to direct your attention to-night, but more especially to one which is particularly interesting from the bearing which it has on the general nature of electric discharge.

We know as a very familiar fact that if we attempt to raise the temperature of a carbon conductor enclosed in a vacuum

\* A discourse delivered at the Royal Institution on Friday evening, February 14, 1890.

† Sir Humphrey Davy had a request before the managers of the Royal Institution on July 11, 1806, that they would set on foot a subscription for the purchase of a large galvanic battery. The result of this suggestion was that a galvanic battery of 2,000 pairs of copper and zinc plates were set up in the Royal Institution, and one of the earliest experiments performed with it was the production of the electric arc between carbon poles, on a large scale. It is probable, however, that Davy had produced the light on a small scale some six years before, and according to M. J. Carlet, observed the arc between carbon points in 1802. See Dr. Faraday's "Life of Sir H. Davy."

beyond a certain limit, not far removed from the melting point of platinum, the carbon begins to volatilise with great rapidity. If an electric glow lamp has passed through its carbon more than a certain strength of current, the glass bulb speedily becomes darkened by a deposit of this volatilised carbon condensed upon it; and experience shows us that we cannot raise the temperature of that carbon beyond a definite point without causing this waste of the conductor to become very rapid. In the highly rarefied atmosphere within the bulb of a glow lamp, the carbon, when at its normal incandescence, must be considered to be projecting off molecules of carbon in all directions, partly in virtue of purely thermal actions, but probably also in consequence of certain electrical effects to be presently discussed. This scattering of the material of the carbon conductor takes place with disadvantageous rapidity from an industrial point of view at and beyond a certain temperature,\* but it exists as well at much lower temperatures than that which is found to determine the practical limit of durability. A curious appearance is found in many incandescent lamps which have been "over run," which shows us that this projection of carbon molecules from the hot conductor is not, perhaps, best described by calling it a vapourisation of its substance, but that the surface molecules are shot off in straight lines, and that they reach the glass envelope without being hindered to any great extent by the molecules of the residual air.



FIG. 1. Glow lamp having the glass bulb darkened by deposit of carbon. Molecular scattering having taken place at a, and shadow of line of deposit produced at b.

If an electric current is passed through an otherwise uniform carbon conductor, which possesses at any one place a specific resistance higher than that of the remaining portion, the current, in accordance with a well known law, there develops a higher temperature, and the molecular scattering at that spot may in consequence be greatly exaggerated. It may be that the deterioration of the conductor at that locality will be so great as to cut it through after a very short time. When the carbon has the form of a simple horseshoe loop, and when this molecular scattering takes place from some point in the middle of one branch, the molecular projection makes itself evident by producing a "molecular shadow" of the other leg upon the interior of the glass. I will project upon the screen an image of the carbon horseshoe loop taken from an old glow lamp, and you will be able to see that the filament has been cut through at one place. At that position some minute congenital defect caused the carbon to have a higher resistance, the temperature at that point when it was in use became excessive, and an intensified molecular scattering took place from that locality. On examining the glass bulb from which it was taken, we find that the glass has been everywhere darkened by a deposit of the scattered carbon, except along one narrow line, (see Fig. 1), and that line is in the plane of the carbon loop and on the side opposite to the point of rupture of the filament.

\* When the rate of expenditure of energy in the carbon conductor is raised until it reaches a value of about 500 watts, or 540 foot pounds per second per square inch of radiative surface, a limit of useful temperature has been reached for economical working, under the usual present conditions of vacuum, design, form of filament, and in different lamps.

I might illustrate to you by a very simple experiment the way in which that "shadow" has been formed. Here is a J-shaped rod: this shall represent the carbon conductor in the lamp; this sheet of cardboard placed behind it, the side of the glass receiver. I have affixed a little spray-producer to one side of the loop, and from that point blow out a spray of inky water. Consider the ink spray to represent the carbon atoms shot off from the overheated spot. We see that the cardboard is bespattered on all points except along one line where it is sheltered by the opposite side of the loop. We have thus produced a "spray shadow" on the board (Fig. 2). The existence of these molecular shadows in incandescent lamps leads us therefore to recognise that the carbon atoms must be shot off in straight lines, or else obviously no such sharp shadow could thus be formed. This phenomenon confirms in a very beautiful manner the deductions of the Kinetic theory of gases. I may remind you that at the ordinary temperature and pressure the mean free path of a molecule of air is deduced to be about four one-millionths of an inch. This is the average distance which such a gaseous molecule moves over before meeting with a collision against a neighbour which changes the direction of its path. Let the air be rarefied, as in these bulbs, to something like a millionth of the ordinary atmospheric pressure, and the mean free path is increased to several inches. The space within the bulb—though from one point of view densely populated with molecules of residual air—is yet, as a fact, in such a condition of rarefaction that a carbon molecule projected from the conductor can move over a distance of three or four inches on an average without meeting with interference by collision with another molecule, and the facts revealed to us by these shadows show that this must be the case. I have also at hand some Edison lamps in which these "molecular shadows" are finely shown, but in these cases the deposit on the interior of the bulb is not carbon but copper, because the molecular scattering has here taken place by excessive temperature developed at the copper clamp by which the carbon filament is attached to the platinum wires.

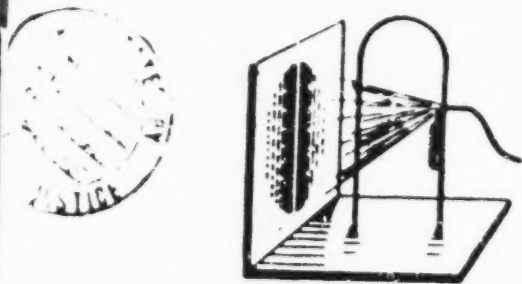


FIG. 2.—"Spray shadow" of a rod throws on tinting paper screen to illustrate formation of molecular shadow in glow lamps.

The theory, however, is the same. The deposit of copper shows a fine green colour by transmitted light in the thinner portions. One curious lamp also before me had by an accident an aluminium plate volatilised within the bulb. The glass receiver has in consequence been covered with a mirror-like deposit of aluminium, which on the thinner portions shows a fine blue colour by transmitted light, and a silvery lustre by reflected light. This lamp also shows a fine "molecular shadow."

These facts prepare us to accept the view that when a glow-lamp is in operation the highly rarefied residual air in the interior of the bulb is being traversed in all directions by multitudinous carbon atoms projected off from the incandescent carbon conductor. I now wish to pass in review before you some facts which indicate that these carbon atoms carry with them electric charges, and that they are charged, if at all, with negative electricity. I may preface all by saying that much of what I have to show you will be seen to be closely related to the phenomena studied by Mr. Crookes in his splendid and classical researches on radiant matter. Our starting-point for this purpose is a discovery made by Mr. Edison in 1881, and which received careful examination at the hands of Mr. Prece

in the following year," and by myself more recently. Here is the initial experiment. A glow-lamp having the usual horseshoe-shaped carbon (see Fig. 3) has a metal plate held on a platinum wire sealed through the glass bulb. This plate is so fixed that it stands up between the two sides of the carbon arch without touching either of them. We shall illuminate the lamp by a continuous current of electricity, and for brevity's sake speak of



FIG. 3.—Glow lamp having insulated metal. Middle plate M sealed into bulb to exhibit "Edison effect."

that half of the loop of carbon on the side by which the current enters it as the negative leg, and the other half of the loop as the positive leg. The diagram in Fig. 4. shows the posi-

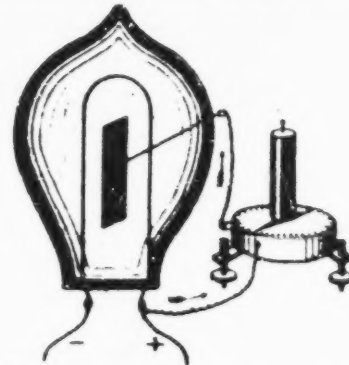


FIG. 4.—Sensitive galvanometer connected between the middle plate and positive electrode of a glow lamp, showing current flowing through it when the lamp is in action ("Edison effect").

tion of the plate with respect to the carbon loop. There is a distance of half an inch, or in some cases many inches, between either leg of the carbon and this middle plate. Setting the

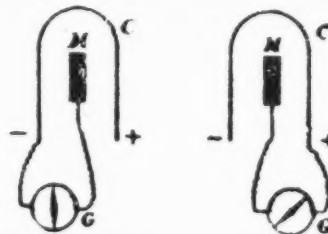


FIG. 5.—Mode of connection of galvanometer G to middle plate M and carbon-horseshoe shaped conductor C in the experiment of the "Edison effect."

lamp in action, I connect a sensitive galvanometer between the middle plate and the negative terminal of the lamp, and you see that there is no current passing through the instrument. If, however, I connect the terminals of my galvanometer to the middle plate and to the positive electrode of the lamp, we find a current of some milliamperes in passing through it. The diagrams in Fig. 5 show the mode of connection

\* Mr. Prece's interesting Paper on this subject is published in the *Proceedings of the Royal Society* for 1895, p. 219. See also *The Electrician* April 4, 1895, p. 436.

of the galvanometer in the two cases. This effect, which is often spoken of as the "Edison effect," clearly indicates that an insulated plate so placed in the vacuum of a lamp in action is brought down to the same potential or electrical state as the negative electrode of the carbon loop. On examining the direction of the current through the galvanometer we find that it is equivalent to a flow of negative electricity taking place through it from the middle plate to the positive electrode of the lamp. A consideration of this fact shows us that there must be some way by which negative electricity gets across the various space from the negative leg of the carbon to the metal plate, whilst at the same time a negative charge cannot pass from the metal plate across to the positive leg. Before I pass away from this initial experiment, I should like to call your

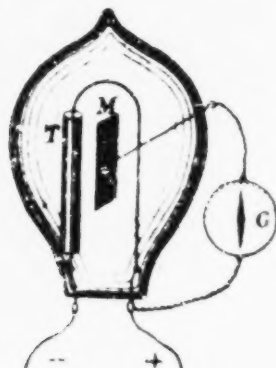


Fig. 6.—Glass lamp having negative leg of carbon enclosed in glass tube. "Edison effect" thereby being annulled or greatly diminished.

attention to a curious effect at the moment when the lamp is extinguished. Connecting the galvanometer as at first, between the middle plate and the negative electrode of the lamp, we notice that though made highly sensitive the galvanometer indicates no current flowing through it whilst the lamp is in action. Switching off the current from the lamp produces, as you see, a violent kick or deflection of the galvanometer, indicating a sudden rush of current through it.

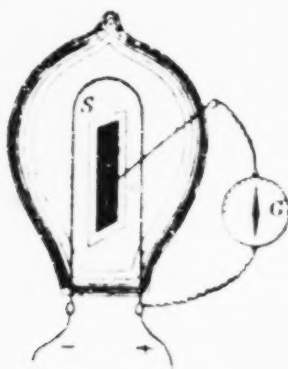


Fig. 7.—Glass lamp having shield of S interposed between middle plate and negative leg of carbon thereby annihilating the "Edison effect."

In endeavouring to ascertain further facts about this effect one of the experiments which early suggested itself was one directed to determine the relative effects of different portions of the carbon conductor. Here is a lamp (see Fig. 6) in which one leg of the carbon horseshoe has been enclosed in a glass tube of the size of a quill, which shuts in one half of the carbon. The bulb contains, as before, an insulated middle plate. If we pass the activating current through this lamp in such a direction that the covered or shielded leg is the positive leg, we find the effect existing as before. A galvanometer connected between the plate and positive terminal of the lamp yields a strong current, as we are furnished between the negative

terminal and the middle plate there is no current at all. Let us, however, reverse the current through the lamp so that the shielded or enclosed leg is now the negative one, and the galvanometer is able to detect no current, whether connected in one way or in the other. We establish, therefore, the conclusion that it is the negative leg of the carbon loop which is the active agent in the production of this "Edison effect," and that if it is enclosed in a tube of either glass or metal, no current is found flowing in a galvanometer connected between the positive terminal of the lamp and this middle collecting plate.

Another experiment which confirms this view is as follows:—This lamp (see Fig. 7) has a middle plate, which is provided with a little mica flap or shutter on one side of it. When the lamp is held upright the mica shield falls over and covers one side of the plate, but when it is held in a horizontal position the mica shield falls away from the front of the plate and exposes it. Using this lamp as before we find that when the positive leg of the carbon loop is opposite to the shielded face of the plate, we get the "Edison effect" as before in any position of the lamp. Reversing the lamp current and making that same leg the negative one, we find that when the lamp is so held the metal plate is shielded by the interposition of the mica, and the galvanometer current is very much less than when the shield is shaken on one side and the plate exposed fully to the negative leg.

(To be continued.)

## MEETINGS OF SCIENTIFIC SOCIETIES, &c.

(To night) FRIDAY, February 21st.

### PHYSICAL SOCIETY.

- 8 p.m. Papers to be read: 1. "On a Carbon Deposition in a Blake Telephone Transmitter." By F. H. HAWES.  
2. "The Geometrical Construction of Direct Reading Scales for Reflecting Instruments." By A. P. THOMSON, B.A.  
3. "A Parallel Motion Suitable for Recording Instruments." By A. P. THOMSON, B.A.  
4. "On the Best Form of Refractometer." By Prof. S. P. THOMSON.

### INSTITUTION OF CIVIL ENGINEERS.

- 8 p.m. Students Meeting. Paper to be read: "Some Types of American Locomotives and their Construction." By C. N. GOSWELL, Student C.E.

### ROYAL INSTITUTION.

- 7 p.m. Lecture: "Magnetic Phenomena." By SHEPHERD BIDWELL, F.R.S.

SATURDAY, February 22nd.

### ROYAL INSTITUTION.

- 3 p.m. Lecture: "Electricity and Magnetism." By the Right Hon. Lord RAYLEIGH, F.R.S.

TUESDAY, February 26th.

### ROYAL INSTITUTION.

- 3 p.m. Lecture: "The Post-Deluvian Period." By G. H. RICHARDS, F.R.S.

### INSTITUTION OF CIVIL ENGINEERS.

- 8 p.m. Ordinary Meeting. Papers to be further discussed: "The Shanghai Water Works." By J. W. H. MOUNTGOMERY, M.Inst.C.E.  
"The Tyburn Water Works." By J. W. H. MOUNTGOMERY, M.Inst.C.E.  
"The Construction of the York Water Works." By J. W. H. MOUNTGOMERY, M.Inst.C.E.

WEDNESDAY, February 26th.

### SOCIETY OF ARTS.

- 8 p.m. Ordinary Meeting. Paper to be read: "The English in Persia." By ALFRED M. STUBBS.

THURSDAY, February 27th.

### SOCIETY OF ARTS.

- 8 p.m. Indian Section. Paper to be read: "The Northern Shan State and the Burma-China Railway." By WILSON SMITH.

### LONDON INSTITUTION.

- 8 p.m. Lecture: "The Flow of British Commerce in India." By Sir ARTHUR LEVEY, K.C.B.

### INSTITUTION OF ELECTRICAL ENGINEERS.

- 8 p.m. Ordinary Meeting. Discussion of the following Papers: "The Theory of Anomalous Reaction in Dynamometers." By JAMES SWINBUR, M.I.E.E.  
"Some Points in Dynamic and Motor Design." By W. B. BROWN, M.I.E.E.